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NORWEGIAN SCHOOL OF ECONOMICS

Bergen/Milan, November 2013

Price adjustment in Norway

An analysis of micro PPI data

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Master thesis in the field of Economics

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ACKNOWLEDGEMENTS

This master thesis was written as part of the Master of Science program at the Norwegian School of Economics, and constitutes 30 ECTS of the study. Whereas most of the work was carried out in Bergen during the third semester of my master, finalizing the work was done during exchange at Università Commerciale Luigi Bocconi in Milan.

The process of writing the thesis has indeed been challenging and demanding, not least next to following a full exchange program. However, it has without a doubt been a period of great learning outcomes and acquisition of deep knowledge in a field I initially had limited insight.

I would like to take the opportunity to direct big gratitude to my supervisor, Professor Øivind Anti Nilsen. From the very beginning, when I was first introduced to this field of research, his enthusiasm and devotion to the work has been invaluable. I am thankful for the time spent giving feedback and guidance along the process, and for sparking interest in a field I would likely not have approached on my own.

I am also very grateful for being entrusted access to PPI data from Statistics Norway for working on this thesis. Analyzing real data from the Norwegian manufacturing sector was not only a necessity for the project; it also made it a lot more appealing. I would also like to express my gratitude to Magne Asphjell, PhD Candidate at the Department of Economics at the Norwegian School of Economics, for providing a prepared dataset for me to analyze. His work and follow-up clarifications definitely made the process a lot more manageable.

Special thanks also go out to my brother Patrick for great input through the process, Hans Tore Hindrum for proofreading, and Irina Isakova for handing in this thesis in my stead.

To all other friends and family members being supportive, either in words or actions;

Grazie mille!

Milan, 11.11.2013

ABSTRACT

We have only limited knowledge about how Norwegian producers change their prices. The aim of this thesis has therefore been to gain greater insight in the price adjustment on producer level in Norway. Throughout the paper I have gathered evidence on the adjustment patterns of Norwegian producers within manufacturing, mining and quarrying. Light has been shed on the field through the presentation of a wide range of descriptive statistics, focusing on the producers' price change frequency, price adjustment size, and duration of price spells, in order to assess whether there are signs of price rigidities. Through the paper the analysis has also been conducted at disaggregated levels, and variations in pricing behavior between different sectors and product groups are therefore presented.

These descriptive findings have been compared to empirical evidence from other European countries. They have further been used to assess the validity of the underlying assumptions of a number of so-called dynamic stochastic general equilibrium (DSGE) pricing models.

The adjustment of Norwegian producer prices appear to be more or less coherent with the adjustment observed in Europe, though some differences are observable. Furthermore, there are indeed signs of rigidities on the producer level in Norway. The producers' prices seem to last longer, have a lower change frequency and larger changes in absolute value than most models of today are able to account for. Additionally, there are clear heterogeneities between different sectors and product categories, as well as seasonal differences, and these factors are causing rigidities that must also be taken into account in the macro model design process.

In general, the findings show that most of the presented DSGE models' underlying assumptions fail to match the empirical evidence. This is measured by their ability to allow for infrequent adjustment, heterogeneity between producers, and decreasing, non-zero hazard rates with annual spikes; important micro evidence presented not only in this thesis, but a growing empirical literature.

Some of the pricing models come closer to matching the empirical findings, and are thereby to a larger extent than others able to incorporate the real adjustment patterns and rigidities. However, there is still an open question what is the most ideal design of such a model.

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1. Introduction

1.1 Motivation and purpose

The field of inflation dynamics and rigidity of prices has triggered interest among economic researchers for several decades. A massive empirical literature has been devoted to shedding a light on this subject, and the wish to gain further insight in the workings of micro level price adjustment has not declined recent years. The last decade this has been especially evident through the empirical work conducted by the Inflation Persistence Network (IPN), a research team consisting of economists from the European Central Bank (ECB) and the national central banks of the European Union (ECB 2005).

A key part of IPN's work has been to analyze consumer (CPI) and producer price indices (PPI), and this effort has resulted in a wide range of empirical papers presenting descriptive statistics on price adjustment in various European countries. Examples are Cornille and Dossche (2008) for Belgium, Gautier (2008) for France and Sabbatini et al. (2005) for Italy all focusing on price adjustment at the producer level[1].

Cornille and Dossche (2008) propose several reasons why it is important to study the producer price adjustment. First of all, these prices play an important role in the macroeconomic models with intermediate goods. The producer level price adjustment responding to shocks to production costs and demand for intermediate goods is transmitted to the consumer level prices. Cornille and Dossche show that the degree of producer price rigidity will be decisive in an inflation-targeting central bank's relative weighing of the inflation on producer level versus consumer level. Furthermore, they stress the need for empirical evidence from both consumer level and producer level, also in models ignoring the distinction between the two levels of pricing. 60 percent of the value of a consumer good is generated on the producer level in industrialized economies (Burstein et al. 2000). If the adjustment of producer prices differs from the adjustment of consumer prices in the aftermath of monetary shocks, it is of great importance to combine evidence from both levels in the model design.

[1] See Table A1 in the appendix for a list of similar descriptive literature from various countries.

Álvarez et al. (2006) emphasize that there is a direct link between the speed of the inflationary adjustment after monetary shocks, and the speed of price adjustment among the individual price agents in the economy. The dynamic response of production, inflation and employment in the wake of monetary shocks depends on both degree and characteristics of nominal price rigidities at the micro level, and it is therefore essential that the central banks' inflation models have microeconomic foundations. While consumer prices are important for central banks' inflation monitoring, the producer level prices are the ones modeled into the macroeconomic policy models (Vermeulen et al. 2007). Hence, in order to improve the design of macroeconomic modeling and policies conducted by central banks, in-depth knowledge about the producer price adjustment is crucial.

The need to delve deeper in the field of price adjustment also rests upon an essential assumption underlying most of today's macroeconomic modeling, namely that monetary policy has implications for the real economy in the short run. Nominal price stickiness at the micro level has been presented as a major factor behind this. In other words, lack of full short-run flexibility of prices causes monetary shocks to affect real variables, and the dynamic adjustment of variables like output and employment depends largely on the degree of nominal price rigidity (Fabiani et al. 2010).

The challenge for economists is to implement these theories into actual economic practice. A broad field of economic literature investigating the price setting behavior of firms in a dynamic optimizing framework has therefore emerged the last decades (Wolman 1999). Numerous authors have presented competing models trying to explain why nominal shocks can have real effects in the economy, and consequently several different theories explaining the causes of the rigidities have been suggested. However, Álvarez et al. (2006) argue that these models and the stabilizing policies of today are still based on highly stilised assumptions when it comes to the micro-level pricing pattern of firms. Hence, the implications of the policies depend on generalized, inaccurate assumptions. It is therefore apparent that there is still a need for deeper insight in the field of price adjustment.

Inspired by the IPN studies, summarized by Vermeulen et al. (2012), this master thesis will be quite descriptive in its form. Monthly micro panel data from the Norwegian PPI will be used to analyze the price dynamics of Norwegian producers. The purpose and methods will be similar to the mentioned literature from the euro area. Empirical findings will be presented in a number of areas. How often do prices change, and by how much? How are the differences between various sectors? Are there any clear seasonal variations? These are some of the questions that will be addressed through this paper, in order to assess whether or not there are signs of price rigidities in the Norwegian manufacturing sector. To the author's knowledge, this has not previously been done on Norwegian data.

1.2 RESEARCH QUESTION

A more specified formulation of the research question is as follows:

How are the price adjustment patterns of producers within the Norwegian manufacturing sector? Does micro data indicate price rigidities on the producer level in Norway, and how are the empirical findings compared to similar literature from other European countries?

Although the summary by Vermeulen et al. (2012) suggests that the various European analyses are fairly coherent on this field, this is not necessarily the case for Norway. It will be interesting to see how unanimous Norwegian producers are with their colleagues in Europe, and possibly in further research investigate what implications an anomaly in this area has on the design of Norges Bank's monetary policies. Are there conditions in Norway indicating that Norway should emphasize measures differently than the rest of Europe?

I also wish to relate my findings to the wide literature of price rigidity research from the last decades. These empirical works are often based on quite differing assumptions when it comes to the price-setting behavior of firms, and the micro evidence from this thesis will be used to assess which theoretical direction is supported by the Norwegian data.

1.3 OUTLINE

This thesis is organized in the following way. Chapter two will present a range of models found in the literature, building on theories of micro level pricing. This will provide a basis for the upcoming analysis, in the sense that it allows the reader to obtain insight in what has earlier been presented in the empirical literature covering price adjustment. It will also give the reader an overview of what has previously been suggested as the major causes of micro level price rigidities.

Chapter three contains detailed descriptions of the data used for the empirical work in this thesis. Explanations of how the dataset was constructed will also be given in this chapter. After having presented the data, the methodological approach is covered in chapter four. Here the aim is to present the assessments that had to be done prior to the empirical analysis, and also to highlight the implications these choices have for the following analysis.

The empirical analysis is found in chapter five, where observations on the price change frequency, price duration and adjustment size will be presented separately. The price adjustment will be studied at a disaggregated level throughout the entire analysis, in order to identify differences in pricing behavior between different sectors and product groups.

To conclude, the empirical findings are summarized in chapter six, together with some closing remarks on the implications on the findings.

2. PRICE ADJUSTMENT LITERATURE

Empirical evidence from the micro level is a prerequisite for better insight in the workings of the economy, e.g. in order to improve the macro models used in implementation of monetary policies. The dominant direction of micro based macro modeling today is the New Keynesian Phillips curve, which links inflation to a measure of real activity (Álvarez 2008). Carlsson and Skans (2009) claim that such models are able to account for the dynamics of inflation in a reasonable way, but that there is still an open issue what is the most ideal design of these so-called dynamic stochastic general equilibrium (DSGE) models.

Through the years several different papers have been produced, presenting different strategies for gaining increased knowledge of the micro price adjustment, both on consumer and producer level. However, the authors of these papers have often reached quite different conclusions on the price adjustment patterns and their implications for calibration of the DSGE models.

Among the pioneers exploring the field of staggered price setting was Cecchetti (1986), who analyzed the price adjustment frequency on U.S. magazines, and Carlton (1986) who focused on the rigidity seen in the light of individual transaction prices. Being the first to analyze micro data for such a purpose, these researchers had quite limited datasets available, which allowed for focusing only on selected parts of the economy. Consequently, the empirical findings of these pioneer studies might have had a less easily transferrable relevance for the other part of the economy (Álvarez 2008). However, with that being said – the importance of such early, seminal works should not be trivialized, as they certainly laid important foundations for the empirical research in the following decades.

A significant challenge, and a clear reason for the shortcomings of the early studies in this field, was access to good microeconomic data. When the underlying data of the CPI and PPI was made available for research purposes, however, the situation changed radically for the better (Klenow and Malin 2011). With Bils and Klenow (2004) leading the way on this field (Álvarez 2008), several authors have produced descriptive analyses based on such datasets. This thesis follows in that tradition.

Considering the large literature of price rigidities having emerged the last decades, the purpose of this chapter is to provide an overview of some of the major directions of the literature on staggered price setting, and DSGE models building on the New Keynesian Phillips curve framework. The models presented in the following sections will be divided into groups according to their view on what is the underlying factor of the price rigidity; sticky information, menu costs, time dependent, cost of adjustment and consumer anger models, respectively[2].

However, this chapter will not only serve as an introduction to the jungle of literature on staggered pricing. It will also provide a basis for assessing the extent to which the findings of this paper support the different established models, i.e. the degree of conformity between the established literature and empirical evidence presented in this thesis[3].

2.1 STICKY CONTRACT / STICKY INFORMATION MODELS

As the name suggests, sticky information models assume that information spread slowly in the economy, and changing economic conditions are thus embedded in real variables like prices and wages with a delay (Mankiw and Reis 2003). In other words, the rigidity of prices is here assumed to be related to a staggered flow of information.

Among the first to formalize the idea that nominal shocks can affect the real economy through imperfect knowledge is Lucas (1972). Under such imperfections the firms are forced to make rational estimates of the coming period's price level, or contract. In Lucas (1973) these theories have been developed into a model where the next period's inflation is given as an estimate driven by past expectation and the output gap. Fischer (1977) follows Lucas in the sticky contract direction by introducing a model where the prices are still predetermined. However, in contrast to the prerequisite of the Lucas models, the price is now allowed to be decided deterministically for several periods ahead, and the price can be set to different levels for the different upcoming periods (Álvarez 2008).

With Mankiw and Reis (2002) this is taken one step further. In their work they suggest a new way of looking at the New Keynesian Phillips curve, where it is the flow of information, and not the price level, that is sticky. Every period each firm has a fixed probability of gaining new information about the economy surrounding them, and thus also a fixed probability of

[2] The selection of literature and division into groups is based on Álvarez (2008), where the conformity of various DSGE models is assessed in a similar way.

[3] A summary of the various pricing models and their underlying assumptions can be found in Table 1, following on page 13.

updating their path of optimal prices. This new price path will then remain until new information is again obtained (Carlsson and Skans 2009).

Other papers present alternative theories to the cause of sticky information. Carvalho (2005) extends the Mankiw and Reis (2002) model by introducing heterogeneity between firms in updating the information set (but importantly *not* heterogeneity in price change frequency). The model of Reis (2006) on the other hand rests upon the assumption that there is a cost for the firm in order to obtain and process information, and that they will therefore be somewhat reluctant to continuously updating their set of information. Lastly, the assumption of Maćkowiack and Wiederholt (2007) is that the firms are free to change their prices at any given time, but that their capacity of processing new information each period is setting a constraint.

These are all models of sticky contract/sticky information, but still they all differ somewhat in explaining how firms each period set their new price. However, a common assumption underlying all of the models is that that prices change on a continuous basis, i.e. every period. Consequently the probability of price change, or the hazard rate[4], equals one for prices aged one period; in other words $h(k) = 1$ for $k = 1$. Additionally, they all imply homogeneity in price change frequency across all the producers in the economy.

2.2 Menu costs models

The price change of a product is likely to induce a cost for the firm, and such a cost is considered to be another possible source of nominal price rigidity. This is the idea behind menu cost models, in which firms are faced with a cost to change their nominal prices. Because of the cost incurred firms do not want to adjust their prices continuously, only when they find it profitable to do so (Álvarez 2008). The term “menu costs” originates from the actual, direct costs restaurants are facing when reprinting menus, but menu cost models are used more broadly than this, and may include both direct costs of materials and labor.

The basic menu cost model was originally presented by Sheshinski and Weiss (1977) and implies that the firms, under a constant rate of inflation, keep nominal prices constant over

[4] The concept of hazard rates will be described in detail in Chapter 4.

intervals with a duration of d* periods. Hence, the probability of price change is ambiguous, with a hazard rate of one for prices aged d*, and zero for lower ages.

According to the model of Danziger (1999) higher menu costs will result in higher expected duration of prices. The probability of price change is thus expected to be endogenously decided, and independent of the timing of the previous price adjustment. The hazard of price change is therefore assumed to be constant (Álvarez 2008). The same is not the case for Dotsey et al. (1999), who present a model where the hazard rate varies between different firms. Some independently drawn firms adjust their price each period, and the price change is identical for all adjusting firms. According to this model the probability of price change is depending on the level of the trend inflation in the economy, but the hazard is homogenous across the firms.

The models presented here all assume that firms are identical in the sense that they have equal price change frequency. In other words – menu cost models do not allow for heterogeneity in price setting. When it comes to hazard rates, the three mentioned pricing models have differing views, although all of them oppose the sticky information idea that the hazard rate is one for each new period.

2.3 TIME DEPENDENT MODELS

In state dependent models like the menu costs models, the firm's decision to change its price comes as a response to changes in the economic environment. Time dependent models are different in this respect, as the decision to adjust price is assumed to be independent from the dynamic state of the economy. Hence, the occurrence of price changes, and hence also the staggering of prices, is determined by exogenous factors (Klenow and Kryvtsov 2008).

A key feature of time dependent models is according to Eichenbaum and Fisher (2003) that the firms are forward looking, and aware that they will only be able to adjust their prices with certain intervals. Risking that they will be unable to increase their prices in the case of a future increase in marginal cost, the firms choose instead to include the expected increase of marginal cost in today's prices. The same goes for expected future inflation, in order to avoid declines in relative prices.

Among the many time dependent models that have been proposed the last decades, particularly two models stand out. In the first one of these, Taylor (1980), the firm decides its

TABLE 1 – UNDERLYING ASSUMPTIONS OF DIFFERENT PRICING MODELS

	Infrequent adjustment	Hazard rate			Heterogeneity in adjustment
		Always non-zero	Decreasing	Annual spikes	
Sticky information					
Carvalho (2005)	No	No	No	No	No
Fischer (1977)	No	No	No	No	No
Lucas (1973)	No	No	No	No	No
Maćkowiack and Wiederholt (2007)	No	No	No	No	No
Mankiw and Reis (2002)	No	No	No	No	No
Reis (2006)	No	No	No	No	No
Menu costs					
Danziger (1999)	Yes	Yes	No	No	No
Dotsey et. al. (1999)	Yes	No	No	No	No
Sheshinski and Weiss (1977)	Yes	No	No	No	No
Time dependent					
Álvarez et al. (2005)	Yes	Yes	Yes	Yes	Yes
Aoki (2001)	Yes	Yes	No	No	Yes
Bonomo and Carvalho (2004)	Yes	No	No	No	No
Calvo (1983)	Yes	Yes	No	No	No
Carvalho (2006)	Yes	Yes	Yes	No	Yes
Galí and Gertler (1999)	Yes	Yes	No	No	No
Sheedy (2005)	Yes	Yes	Yes	No	No
Taylor (1980)	Yes	No	No	No	No
Taylor (1993)	Yes	Yes	No	Yes	Yes
Wolman (1999)	Yes	No	No	No	No
Convex costs of adjustment					
Kozicki and Tinsley (2002)	No	No	No	No	No
Rotemberg (1982)	No	No	No	No	No
Consumer anger					
Rotemberg (2005)	Yes	Yes	Yes	No	No

Note: The table is an excerpt from a similar table found in Álvarez (2008), summarizing the underlying assumptions of the different models presented in this chapter. The table will in the conclusion of the thesis be relevant also in assessing the conformity of the listed models with the micro evidence from the empirical analysis.

prices by contracts that remain fixed for a given number of periods. The hazard rate is thus zero for a certain time, before it in period d^* switches to one at the end of the contract.

Even more momentous in the field of staggered price setting is perhaps the work of Calvo (1983). In fact, the Calvo pricing rule is today the most used and commonly accepted derivation of the New Keynesian Phillips curve among the many DSGE models (Álvarez and Burriel 2010), and numerous later works build on its framework. Contrasting to the model by Taylor (1980), Calvo assumes that the firms adjust their prices on a random basis. The price rigidity is thus introduced to the model by letting the firms change their prices with a probability θ, whereas the prices remain unchanged with a probability $(1 – \theta)$. Since the Calvo model assumes that this probability is random and unchanged across periods, the hazard is constant according to the Calvo model.

Building on these seminal works, a broad literature has emerged on this field through the years, with numerous authors presenting their variations of time dependent pricing models. In addition to the two models already presented, several alternative versions of time dependent models could be mentioned. Bonomo and Carvalho (2004) follow Taylor's view of fixed duration contracts, while Wolman (1999) presents a version of the Calvo model in which the hazard rate is fixed up to a certain price duration, when all firms are forced to adjust their prices. A different view is given by Sheedy (2005), with upward sloping hazard rates, in contrast with the original Calvo model.

None of the time dependent models mentioned so far allow for heterogeneity in price change frequency across producers. However, several other models do. The Taylor (1993) model introduces heterogeneity by letting the duration of price contracts differ between producers. According to this model the hazard rates are increasing. Aoki (2001) brings heterogeneity into the picture by considering two different sectors in the economy – one flexible with continuous price change, and one rigid, where the price change follow a Calvo (1983) pattern. The hazard rate is constant after the second period. This model has been further developed by Carvalho (2006) which allow for several more sectors, and a decreasing hazard rate. Also following a Calvo pattern is Galí and Gertler (1999). Despite differing from the original model on several areas, not only when it comes to heterogeneity, this model indeed assume a constant hazard rate like the Calvo (1983) model.

Finally, Álvarez et al. (2005) present a modified Calvo model, in which a combination of different groups of Calvo agents are used to estimate aggregate hazard functions of price spells. Using different groups with different pricing strategies lets the model allow for heterogeneity. In their paper they present an annual Calvo model where producers reset their prices every 12 months, but keep them unchanged for the remaining time. The result is an aggregated hazard rate that is decreasing, with annual spikes every 12, 24, 36… periods.

2.4 CONVEX COSTS OF ADJUSTMENT

For some other pricing models an essential assumption is that the cost of adjustment follows a convex pattern. A couple of examples of this sort are Rotemberg (1982) and Kozicki and

Tinsley (2002). Like with the menu cost models the price adjustment decision is here based on the cost of changing prices, but whereas the menu cost models imply that price-setters will delay the price change until the incurred cost can be justified, the opposite is the case for models assuming a convex cost of adjustment. The increasing cost of adjustment implies that producers will adjust their prices as frequently as possible, and the hazard rate is consequently constant at one for all prices aged one period. Because all price setters change their price every new period, these models leave no room for heterogeneity in price change frequency.

2.5 CONSUMER ANGER MODELS

Reluctance to increase the price of a product fearing that consumers will react negatively to such a change is another theory of nominal price stickiness. Models building on such theories claim that consumers' insight and information about the underlying factors of price setting is limited and varying over time, and that their resistance to price increases will also be changing over time. The firms will thus adjust their prices with certain intervals, depending on the views of the consumers. A model of this kind is presented by Rotemberg (2005). Here the price change frequency is equal for all producers, as they are all exposed to the same irrational consumer variables. The predictions of the model will equal that of Calvo (1983) in cases where the consumers' view on fair pricing is constant over time. Then also the hazard rate will follow a constant pattern. However, this model assumes that consumers are irrational in their assessment of the producers' price adjustments, and there is consequently no clear answer to what is the actual form of the hazard rate (Álvarez 2008).

3. PRESENTATION OF THE DATASET

As mentioned in the introduction, this thesis will present descriptive facts on a number of areas regarding the price adjustment pattern of firms. The empirical work in this paper is conducted using micro data from the Norwegian manufacturing sector. The dataset has been constructed by combining two different data sources, both obtained from Statistics Norway (SSB). The price data are raw data from the commodity price index for the Norwegian manufacturing sector (VPPI[5]), given as monthly price observations. These price observations have been linked to the structural statistics for manufacturing industries, mining and quarrying, in order to provide a wide amount of information regarding the companies reporting their prices.

3.1 COMMODITY PRICE INDEX FOR THE INDUSTRIAL SECTOR

The dataset used in this paper consists of monthly micro data collected by SSB for calculation of the VPPI. In theory, such a dataset allows us to analyze price rigidity on the individual producer level. At the aggregate level, the index is measuring the actual inflation on the producer level and is a key part of the short-term statistics that monitor the Norwegian economy. The VPPI is closely connected with the PPI, with the main difference being that the former may be subject to revisions in retrospect. Developments in the Norwegian market, export and import market is calculated on the basis of this index, together with the PPI and the price index for domestic first-hand production (PIF) (SSB 2013a). Only data on domestic production will be used in this analysis.

The VPPI comprises all commodities and services produced by companies within manufacturing, mining, mining support service facilities, oil and gas extraction, and energy supply (SSB 2013a). The price quotes are consequently obtained from firms operating in these sectors. A selection of producers from these sectors report their prices on a monthly basis, and large, dominating establishments are targeted in order to secure a high level of accuracy and relevance (Asphjell 2013). The selection of respondents is furthermore updated

[5] Norwegian abbreviation for "vareprisindeks for industrinæringene", translating into "commodity price index for the Norwegian manufacturing sector".

on a regular basis, in order to make sure that the indices continuously are being kept relevant compared to the development of the Norwegian economy (SSB 2013a).

The required information for the PPI, VPPI and PIF are all collected in the same survey, and responses are collected both through questionnaires and electronic reporting. Compulsory participation ensures a high response from the questioned producers. To make sure that the indices hold a high quality the gathered data is subject to several controls aiming at identifying extreme values, mistypings and similar mistakes.

3.2 STRUCTURAL BUSINESS STATISTICS

As already mentioned, the dataset used in the following analysis is constructed by connecting PPI data to data from industry statistics. The structural business statistics for manufacturing, mining and quarrying is reported on a yearly basis, and is a part of SSB's industry statistics that provides detailed information about the activity in the specified industries (SSB 2013b). For each establishment represented in the dataset there are thus information listed on a number of variables related to their economic activity, including employment numbers, wages and the like.

The structural statistics are only given for the companies within certain industries, and this lay down constraints on the final dataset. As these structural statistics are linked to price data from the VPPI, the final sample of price observations only account for a proportion of the full spectrum of industries presented in the producer price index. Other industrial sections than manufacturing, mining and quarrying, for example related to agriculture, energy, transportation and service industries, will not be included in the empirical analysis of this thesis.

3.3 STANDARD INDUSTRIAL CLASSIFICATION

The observations in the dataset are classified by industry, based on SSB's Standard Industrial Classification (SIC2002). This is a statistical standard that codes each product in a detailed, hierarchical code structure according to the economic activity to which it belongs. SIC2002 is based on the EU classification standard, NACE Rev. 1.1[6], to ensure that statistics are

[6]See (SSB 2013c) and Eurostat (2005)

comparable across different countries (Bore and Skoglund 2007). The purpose of such a standardization is thus to create a uniform classification, both within Norway and in an international perspective, and group homogeneous products together under the same code. In the dataset these industry codes are provided at a five digit level, which is the most detailed level of the SIC2002. This means that the economic activity of each individual product can be traced at a fairly detailed level. A list of the industries (at two digit level) represented in the dataset can be found in Table A2 in the appendix.

The Norwegian industrial structure is regularly subject to changes. SSB (2008), for example, argues that private and public services have experienced a significant expansion in recent years. Because of this dynamic environment it is necessary to revise the industry standard from time to time. SIC2002 was used as a classification standard from the beginning of 2002 to the end of 2008. From January 2009, this was replaced by SIC2007, a more detailed industry classification based on NACE Rev. 2, where the number of sub groups within different industries was significantly increased. In addition to the increase in scale, the numerical order of the industries was changed in the new standard (SSB 2008). These differences prevent the use of the two standards interchangeably. The dataset used in this thesis reports price observations in the interval from 2002 to 2009, and the establishments are therefore primarily categorized by SIC2002. If SIC2007 had been used as the classification standard, the vast majority of the dataset would have missing value for the industry. For that reason SIC2002 has been used as classification standard of this empirical work. For observations in 2009, when the SIC2002 classification is no longer listed, the products have been given an industry code based on the previous years' SIC2002 classification.

3.4 FINAL REMARKS ON SAMPLE SELECTION

The merging of the two data sources provides a starting point for the analysis, but some requirements have to be met for products to be included in the final dataset[7]. First of all, products in the sample must be represented with price observations in at least 24 subsequent months. The sample only cover privately owned companies with 10 or more employees, and multiplant establishments are left out of the sample. Yearly growth rates for wage and sales

[7] The preparations of the dataset have been done by Magne Asphjell, PhD Candidate at the Department of Economics, Norwegian School of Economics. Further details concerning the decisions made in construction of the dataset can be found in Asphjell (2013).

also narrow the sample, as growth observations outside the [.01, .99] interval have been eliminated from the dataset. Additionally, since very large monthly price changes are believed to reflect quality changes and not only simple month-to-month pricing decisions, observations following price changes outside the [.01, .99] interval have been identified as new products (Asphjell 2013).

The dataset used in the upcoming analysis consists of 94,212[8] individual price observations. The number of establishments is 388, and the total number of unique products that are produced is 1803. The observations are distributed across 23 different industries categorized by the SIC2002 standard, and span a time period from 2002 to 2009.

As can be seen from Table A3 in the appendix, the observations have further been grouped according to product category. From this we can see that 20 percent of the listed price quotes are from non-durable food related products, while 8 percent are from non-durables not related to food, e.g. production of textiles and footwear. Another 8 percent of the price quotes are from producers of consumer durables, like furniture and domestic appliances. 14 percent are from capital goods (e.g. manufacture of machinery), and approximately 50 percent are from intermediate products. As the PPI covers producer level sales it seems natural that intermediate goods account for a major proportion of the final dataset.

A last consideration done in the construction of the dataset is the proportion of temporary price reductions. This is an important qualitative difference between the price adjustment on consumer and producer level (Cornille and Dossche (2008). At the consumer level it is not unusual that price setters are experimenting with reduced price for a short period, before the price returns to its original level. Empirical work that has been done on consumer price data, for example Nakamura and Steinsson (2008), therefore usually control for such temporary price changes. However, it has been shown that that price adjustments of this kind, also known as price changes in a so-called V-pattern, are very rare at producer level (Cornille and Dossche 2008). Among all the price quotations in the dataset used in this paper only 0.25 percent are set in such a manner. This suggests that the need to correct for such an adjustment pattern is rather subdued.

[8] This final number is obtained after removing 96 price quotes from an original dataset consisting of 94308 observations (the dataset prepared by Magne Asphjell). These price quotes were categorized as sector 51 - "Wholesale trade and commission trade, except of motor vehicles and motorcycles" - according to SIC2002. Including these would probably not have made a significant difference, but they have removed for lack of relevance (being the only observations from retail trade).

4. METHODOLOGICAL APPROACH

The empirical work of this paper is inspired by similar studies done on PPI data from other countries earlier, and it will follow the same pattern as these earlier works[9]. The main goal of the analysis is to describe the pricing pattern across different industries and product groups at producer level. Before initiating the analysis it will be necessary to make a number of methodological choices, in the same way as previous literature before me. These decisions are related to the treatment of the dataset, and particularly how we deal with so-called censored observations. The choices made here may be decisive for the empirical results, and for this reason this section of the thesis will be devoted to explaining the assessments and methodological choices that have been made.

4.1 AGGREGATION OF DATA

A central question that arises prior to the analysis is how to deal with aggregation of price spells over different price trajectories and industries. The different possibilities must be assessed in order to find the method being most appropriate for the empirical work (Fabiani al. 2010).

When calculating the aggregate figures for the price adjustment across the dataset it is possible to use industry weights. This implies that one first calculate the average estimates, e.g. the price change frequency, for products classified in the same industry group, before a weighted average subsequently is calculated across all industries.

The motivation behind such a weighted aggregation is to control for variation in price setting pattern in different industries. Differences across industries can potentially create skewed estimates if not taken into account. However, such a weighing scheme is not used in this empirical work. This is due to several factors, but first and foremost related to a lack of industry weights comparable to the ones used in the comparable PPI literature[10]. Whenever

[9] A list of relevant comparable literature is given in Table A1 in the appendix.
[10] In retrospect I'm aware that other variables, like sales or employment, could potentially be used as industry weights. However, this would be clear deviations from the comparable literature which all uses official NACE weights, and I fear that constructing my own weights would do more harm than good in regard of comparability to the previous literature.

these previous papers have presented weighted figures, these have been produced with official NACE weights from their respective countries. Not having succeeded in obtaining such weights for the Norwegian data, the empirical findings will be presented as unweighted estimates.

Even though the ideal situation would have been to present weighted estimates also in this thesis, I will argue that it is not crucial for the relevance of the findings. First of all, much of the empirical analysis will be conducted at a more disaggregated level, for which weighing is assumed to be less critical. Additionally, the comparable literature is often not solely presenting weighted estimates, but also referring to unweighted estimates.

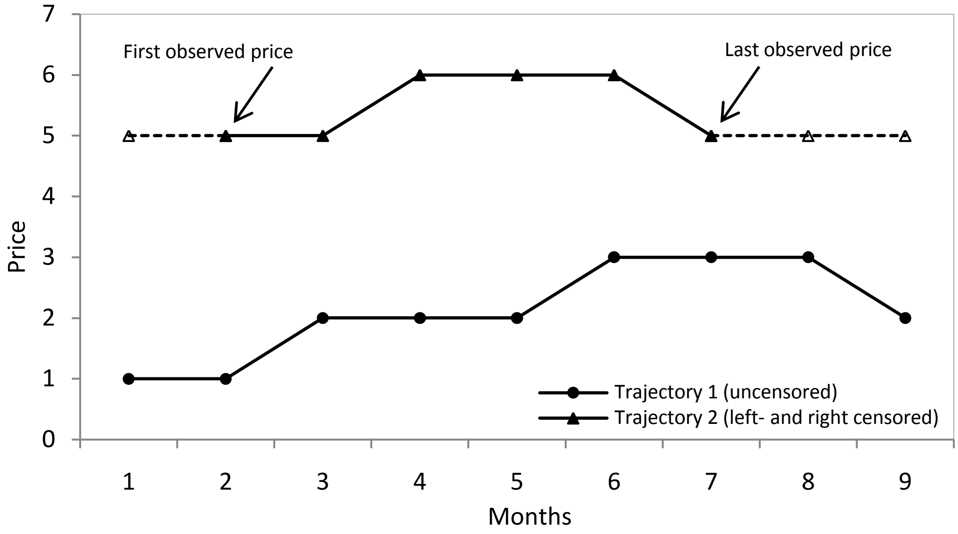
Furthermore, the selection of industries in the dataset used in the following analysis is cleared of industries usually highlighted as the "extremes" within price adjustment, i.e. industries often referred to as most likely to induce a bias if left uncontrolled for. More precisely, the sample of observations in this thesis is based on the structural industry statistics for manufacturing, mining and quarrying industries. Hence, no elements of operations related to for example the energy industry is represented in the dataset. Firms in the energy sector are known to have a much higher adjustment frequency than average, and it is possible to argue that this could have given biased estimates if left unweighted. Contrasting to the energy sector are service industries, also often argued to have a distinctive pricing pattern. Change frequency is here often relatively low because of high labor intensity (Cornille and Dossche 2008). However, service industries and other labor-intensive industries are not represented in the dataset used in this paper either.

Thus, on the basis of these arguments, and in the absence of appropriate weights for the industries and product groups over the sample years, the empirical analysis following in the next chapter is conducted without a weighing scheme. Still, being aware of this practice makes it possible to assess possible consequences of the choice when the final results are at hand, and a comparison with findings from former literature is available.

4.2 BASIC DEFINITIONS

To make it easier for the reader to follow this methodological review, some basic definitions underlying the empirical work will here be presented, in the same way as it is done by e.g. Baudry et al. (2004).

FIGURE 1 – PRICE TRAJECTORIES



Note: The figure is taken from Fabiani et al. 2010

$P_{ij,t}$ is an individual price quotation, i.e. the price level of a product *j*, sold by a firm *i* in a specified time period *t*. In the dataset used in this thesis, the observations are given on a monthly basis, and $P_{ij,t}$ is thus interpreted as the price observed on a product defined by (*i*, *j)* in a specific month.

A price spell is an uninterrupted sequence of unchanged price on a product *(i, j)*, i.e. a sequence of prices $P_{ij,t}$, $P_{ij,t+1}$, … , $P_{ij,t+k-1}$, where $P_{ij,t+s} = P_{ij,t}$ for *s=1,… , t+k-1*. The duration of each price spell, *k*, is therefore given by the number of months between two price changes.

A price trajectory is a sequence of successive price spells, or in other words a whole price series from start to end for a specific product *(i, j)*. The length of each product's individual price trajectory is therefore given as the sum of the product's price spells. Figure 1 provides a graphical presentation of the different concepts and the connection between them. In the figure price trajectory 1 consists of four price spells of different durations, while price trajectory 2 is given by three price spells, all lasting three months.

According to Aucremanne and Dhyne (2004) two different methods can be used to measure the degree of price rigidity at the micro level. The analysis can either be based on the duration of the price spell, or the frequency of price changes. Equal results from the two methods will only occur if the dataset does not contain so-called censored price spells (Veronese et al., 2005). Censored price spells are prices in the dataset without specified starting and/or ending month, which will be the case for price spells at the beginning and end of every price trajectory. This is illustrated in Figure 1. The first price spell of trajectory 1 is left censored, as price observations only occur from month 2 in the dataset. Thus, the actual starting month of the first price spell cannot be stated with certainty. Similarly, the third price spell is right censored, since no price data is observed after month 7.

Since the two different methods only give equal results under the strict assumption of no censored price spells, it is important to consider the advantages and disadvantages of the two methods. In the following sub-chapters the two measures of price rigidity, the frequency approach and the duration approach, respectively, will be presented in detail, in order to assess the differences between the two methods.

4.3 THE FREQUENCY APPROACH

The first of the two alternative methodological approaches mentioned above, the frequency approach, is well covered in the literature, and has been used by Bils and Klenow (2004) among others. This approach estimates the price change frequency as the share of price quotations changing in a given period. The durations of the prices can subsequently be calculated implicitly as the inverse of the change frequency.

I follow the same strategy as Álvarez et al. (2010), and start by defining a set of binary variables for each price quotation, $P_{ij,t}$.

$$DEN_{ijt} = \begin{cases} 1 & \text{if } P_{ij,t} \text{ and } P_{ij,t-1} \text{ are both observed in the dataset} \\ 0 & \text{if } P_{ij,t} \text{ is observed in the dataset, but not } P_{ij,t-1} \end{cases} \quad (1)$$

DEN_{ijt} is a binary variable given a value if for a product *(i, j)*, price quotations are available in two successive months. The sum of this variable over all months is given by $\sum_{t=2}^{T} DEN_{ijt}$. This sum gives the total number of price quotations that are included in the frequency calculations for the specific product, j. Worth emphasizing is that the summation goes from period t = 2, i.e. from the second month of each price trajectory. This is a detail that picks up the fact that it will not be possible to determine whether the first price quoting a price trajectory is new or old. Consequently this first month is excluded from the calculation of the total number of price quotations.

Furthermore, another binary variable is defined as

$$NUM_{ijt} = \begin{cases} 1 & \text{if } P_{ij,t} \neq P_{ij,t-1} \\ 0 & \text{otherwise} \end{cases}, \tag{2}$$

This variable gains value whenever the price of a product *(i, j)* in a given month differs from the price listed in the previous period. In the same manner as with (1), the sum of this variable over t, $\sum_{t=2}^{T} NUM_{ijt}$, will provide the total number of prices changes over time for a specific product *(i, j)*.

With a small adjustment of equation (2) we get yet another binary variable, which is given a value only when the price change is an increase. This is presented in equation (3) as

$$NUMUP_{ijt} = \begin{cases} 1 & \text{if } P_{ij,t} > P_{ij,t-1} \\ 0 & \text{otherwise} \end{cases}, \tag{3}$$

in cases where the price in month *t* is higher than in the previous month.

Similarly we can find a binary variable identifying price decreases

$$NUMDW_{ijt} = \begin{cases} 1 & \text{if } P_{ij,t} < P_{ij,t-1} \\ 0 & \text{otherwise} \end{cases}, \tag{4}$$

in cases where the price in month *t* is lower than in the previous month.

From these binary variables one can easily calculate the price change frequency for each product. On equation form this can be shown as

$$F_{ij} = \frac{\sum_{t=2}^{T} NUM_{ijt}}{\sum_{t=2}^{T} DEN_{ijt}} \tag{5}$$

where the frequency of price changes, F_{ij}, is given as the number of price changes as a share of the total number of price quotations, summarized over the product's price trajectory. The frequency of increases and reductions separately can be found in the same way, using the binary variables (3) and (4).

In practice, not using industry weights in the calculation implies that equations (1) through (5), with minor modifications on notation, define not only the change frequency at the product level. These equations can also be used to calculate the total change in frequency for the aggregate dataset. Such a procedure would in other words mean that the price change frequency, F, is estimated as an unweighted average of the number of changes in rates of total price quotations across products and industries.

Having calculated the price change frequency, the average price duration can implicitly be estimated as the inverse of the frequency (Veronese et al. 2005). If it is assumed that manufacturers change their prices in discrete time intervals, this average duration is stated as

$$\bar{d} = \frac{1}{F} \tag{6}$$

If it on the other hand is believed that the price adjustment is done in continuous time, i.e. assuming that the prices change continuously over the periods, Veronese et al. suggest that the average duration implicitly can be calculated as

$$\bar{d} = \frac{1}{ln(1-F)} \tag{7}$$

However, as the empirical findings will show, there is little indication that price setting is done in continuous time. Additionally, Veronese et al. (2005) claim that equation (7) should only be used in cases where the model at hand is a constant hazard model. As we shall also observe in the analysis, there is little evidence that this is the case. I therefore chose to limit the duration analysis to equation (6), in addition to the direct estimates calculated through the duration approach, to be presented in the following sub-chapter. [11]

A positive feature of the frequency approach is that it utilizes all the relevant information available in the dataset. According to Aucremanne and Dhyne (2004), it can therefore be said to be a way to circumvent one of the major drawbacks the duration approach entails, namely a potential selection bias, which will be described in more detail in the next sub-chapter. In short this bias is related to the treatment of censored data, and the fact that long price spells

[11] Veronese et al. present additional industry weighted models for estimating change frequency. These have not been assessed in this thesis, but can be observed on page 11 and 12 in Veronese et al. (2005).

are at a relatively higher risk of being eliminated from the dataset when controlling for censored price spells.

The frequency approach also has its weaknesses, though, particularly evident when it comes to the implicit estimation of the price duration. Alvarez et al. (2010) show that this method *only* allows for the analysis of variations in price duration across product categories, i.e. differences in averages across defined groups. Hence, it is not possible to analyze the full distribution of price durations.

4.4 THE DURATION APPROACH

The second method of analysis, the duration approach, measures the lifetime of the individual price spells directly, in other words how many months a price remains unchanged from a price change to the next. Change frequency can in turn be calculated implicitly as the inverse of the price duration. This approach is thus going in the opposite direction of the frequency approach.

In the same manner as in the frequency approach, an assessment of which aggregation is most ideal should be done also when using the duration approach. Also in calculating the price duration there are several ways to aggregate the data. According to Veronese et al. (2005), these aggregation methods give very similar results if the number of price spells is large enough that reasonably homogeneous durations can be assumed across the various price trajectories. Nevertheless, they emphasize that the choice of aggregation method potentially could be highly decisive for the results you end up with.

One possibility is to calculate a simple average of all price spells across all products' price trajectories. Alternatively, one could also here first calculate the average duration of price spells within each price trajectory, and then in turn aggregate these averages across all price trajectories. If the first method is used, an unweighted average of all price spells' duration will be calculated. This can be shown by

$$\bar{d} = \frac{1}{N_{spells}} \sum_{j=1}^{n_j} \sum_{s=1}^{N_{sj}} d_{js} = \frac{N_{price\ quotes}}{N_{spells}} \tag{8}$$

where j indicate product, n_j is the total number of products, s refers to a specific price spell, d_{js} is the duration of price spell s, and N_{sj} is the number of price spells given for an individual product, j.

Veronese et al. (2005) stress that equation (8) will entail the risk of disproportionate weighting to products with relatively high change frequency, as explained in a previous sub-chapter. To circumvent this problem they therefore choose to present a number of alternative equations for calculating the price duration, all including industry weights in the calculation.

Still, based on the arguments presented in the sub-chapter on aggregation of data I will also in the estimation of price durations conduct the empirical estimation without industry weights. The same arguments as before are underlying this decision, namely that it will still be possible to produce relevant, comparable estimates in the analysis. I therefore choose to proceed with equation (8) as a starting point in the forthcoming duration approach analyzes.

According to Veronese et al. (2005) one of the main benefits of the duration approach is that one can estimate the full distribution of price durations in each period, and not just the median and average. By using the duration approach, both median and percentile distributions of durations can be reported. Furthermore, they show that only this approach makes it possible to calculate the hazard and survival functions. The methodology behind the hazard calculation will be elaborated in the following sub-chapter.

Aucremanne and Dhyne (2004) argue, however, that the duration approach should only be used on uncensored price spells, and refer to this as a major drawback of this approach. This is a potential source of selection bias that may affect duration estimates, as long price spells are more likely to be censored, and therefore excluded from the calculation.

Different authors have different ways of tackling this problem, though. Veronese et al. (2005) present two contrasting strategies; full correction of censored price spells and no correction, respectively, whereas Álvarez et al. (2010) present a middle way alternative. The latter is the one I have chosen to follow in the empirical estimations, attempting to reduce the bias. More detailed descriptions of the implications of this choice will be shown in the empirical chapter.

Because of the selection bias entailed by the duration approach, I choose to follow Álvarez et al. (2010) in disregarding the fact that an estimate of the price change frequency can also be found as the inverse of the average price duration. In the forthcoming empirical analysis of change rate frequency I therefore only utilize the method presented in sub-chapter 4.3.

4.5 HAZARD FUNCTIONS

In order to investigate the duration of the prices more thoroughly I will also produce hazard rates for various samples of the dataset. A hazard function is a tool often used to describe the duration of economic time series data, such as the price data analyzed in this paper. As mentioned in the previous sub-chapter, such hazard functions can be estimated only if the duration approach is used. Consequently, the estimation of hazard rates follows the same rules as this approach, in terms of the assessment of censored price spells.

The hazard function indicates the probability of a price change after *k* months, given that the price has remained unchanged over the previous *k-1* periods (Álvarez et al. 2010).

$$h(k) = Pr\{p_{t+k} \neq p_{t+k-1} | p_{t+k-1} = p_{t+k-2} = \dots = p_t\} \tag{9}$$

k is thus a non-negative variable indicating the time passing before a price "dies", or to put another way - the duration of a single price spell. Veronese et al. (2005) and others follow a so-called Kaplan-Meier method, and estimate the hazard rates for all possible price durations as a ratio given by the number of price spells ending after k months, h_k, divided by the share of price spells which still remains unchanged, R_k.

$$\hat{\lambda}(k) = \frac{h_k}{R_k} \tag{10}$$

Thus, R_T will at any given time correspond to the number of price spells with duration equal or higher than *k*.

As seen in chapter two, when presenting different theoretical directions of price change modeling, this is a field of discussion in the literature. The various DSGE models often reach quite different conclusions on what is the correct pattern of the hazard function. The empirical findings related to the hazard of price changes will therefore be important in assessing the validity of the various models.

5. EMPIRICAL ANALYSIS

As emphasized in the introductory chapter, the main objective of this thesis is to gain new insights in the price adjustment taking place in the Norwegian manufacturing sector. The analysis section of this paper will therefore present characteristics of the Norwegian producers' pricing pattern. The degree of price rigidity has a critical impact on the design of the DSGE models and the effect of monetary policy (Gautier 2008), and it will be of great interest to assess the topic of price rigidities at the producer level in Norway. Different indicators known from the literature on micro price adjustment will be used for this purpose; the frequency, duration and magnitude of the producers’ prices, respectively. If a price has long duration, low change rate, or relatively large changes in absolute value, the price is considered to be rigid (Gautier 2008).

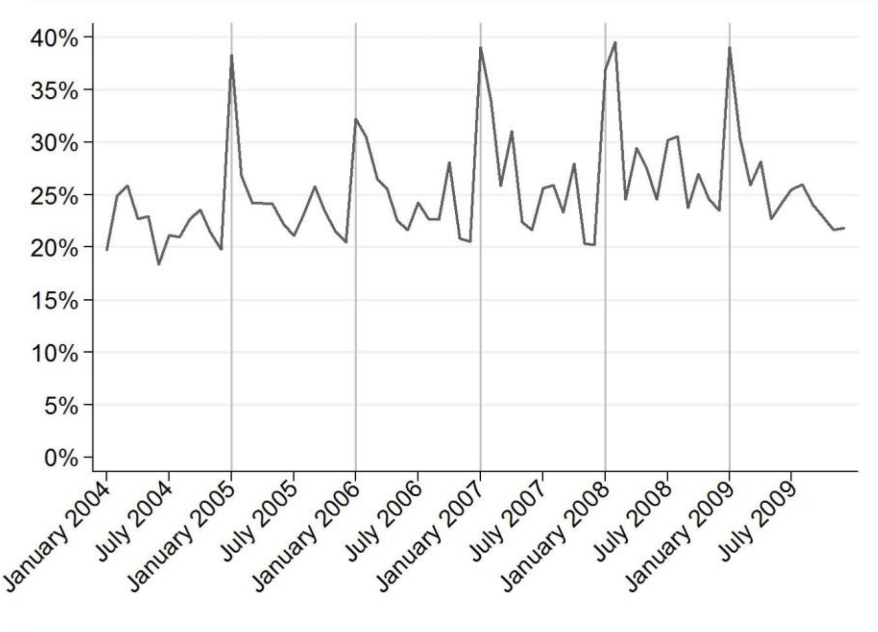
5.1 THE FREQUENCY OF PRICE CHANGES

As a first step in the analytic work, I want to highlight findings related to the price change frequency. In this work, the frequency approach is used as described in the methodology section of this thesis.

To get an overview of how the price change frequency evolves over time, the monthly averages ranging from January 2004 to December 2009 have been plotted in Figure 2. As described in the methodological section of this thesis, these averages are estimated as the number of price changes within a given month, divided by the total number of price quotes in the month.

The figure reveals a pattern similar to what we find in the comparable literature from Europe. Simply by looking at this figure we understand that the price setting of Norwegian producers follow a seasonal pattern, where the frequency of price changes is substantially higher at the beginning of the year. Also through the rest of the year the change frequency seems to follow a similar pattern from one year to the next. Also interesting to see is that the change frequency apparently follows an upward sloping trend through the years plotted in the figure. Starting at a change frequency seemingly averaging at 22-23 percent the trend increases slowly but steadily all the years, ending up at a level averaging around 25 percent.

FIGURE 2 – MONTHLY FREQUENCY OF PRICE CHANGES



Note: Average frequencies are given as number of price changes within a given month divided by the total number of price quotations in the month. A figure covering the full sample 2002-2009, and explanations of why 2002-2003 has been left out of the analysis, can be found in Appendix 5.

The main findings from the Norwegian dataset are presented in Table 2 alongside findings from other European countries, as found in Vermeulen et al. (2012). In this table we can observe that approximately one quarter of the prices change every month. The change frequency among Norwegian producers is thus roughly the same as we observe for the rest of Europe, although it admittedly is the highest of all listed average frequencies.

We also see that there is a higher monthly rate of price increases than price decreases. This applies to the dataset as a whole, but also when we observe certain industries and product groups separately (see e.g. Table 3). Consequently, this is a finding that applies broadly to the producer level in Norway, and not something that is colored by a few and particularly influential, volatile industries.

That there is a higher fraction of price increases than price decreases is something found also in equivalent material from other European countries. Thus it can be said that the Norwegian findings are coherent with what has been proven earlier. However, when comparing the Norwegian fraction of price decreases with the findings of other European countries, it seems that the Norwegian findings do differ somewhat from the European. The estimates from the

TABLE 2 – AVERAGE MONTHLY PRODUCER PRICE CHANGES IN EUROPEAN COUTRIES

	Frequency of price adjustments				
	Changes	Increases	Decreases	Fraction of price decreases	Inflation
Belgium	23.6	12.8	10.9	45.9	0.12
France	24.8	13.8	11.0	41.9	0.09
Germany	21.2	11.8	9.4	44.4	0.09
Italy	15.3	8.5	6.8	45.0	0.14
Portugal	23.1	13.6	9.5	41.2	0.17
Spain	21.4	12.2	9.2	43.2	0.17
Euro area	20.8	11.6	9.2	43.8	0.11
Norway	25.4	15.5	9.9	39.0	0.17

Note: Estimates are given in percent, average share of prices changed per month. For the other European countries the estimates are taken from Vermeulen et al. (2012). A table summarizing the reference literature for the above listed countries is given in Table A1 in the appendix. The Norwegian inflation figure is average monthly change in CPI from 2004 to 2009.

Norwegian data show a significantly lower proportion of price reductions. With a monthly rate of about 9 percent and total fraction of price decreases which is five percent below the average for Europe, it seems that Norwegian producers on this field have a slightly different pricing behavior than their continental colleagues.

This finding may also be seen in relation to the average inflation in the sample period. The average monthly change in CPI in Norway was 0.17 percent from 2004 to 2009, while the average for the Euro area as a whole was far lower at 0.11 percent (Vermeulen et al. 2012). With an inflation rate significantly higher than the average, a higher fraction of price increases seems reasonable. However, this conclusion is not perfectly consistent, as other countries have inflation rates on the same level as Norway, but still price decrease fractions closer to the European average.

Even though we observe a slightly lower fraction of price decreases in Norway than in the literature in general, there is reason to claim that the price decreases occurs fairly frequently also in a Norwegian perspective. A frequency ratio just below 40 percent indicates that it is not uncommon for Norwegian producers to adjust their prices downward. Nevertheless, downward nominal rigidity will occur in cases where the distribution of price changes is a skewed towards the positive side of price change scale (Cornille and Dossche 2008). The estimates in Table 2 may therefore be interpreted as a sign that there is a slightly larger degree of downward price rigidity among Norwegian producers, compared to the findings of other European countries.

TABLE 3 – MONTHLY PRICE CHANGE FREQUENCY, BY PRODUCT CATEGORIES

	Frequency of price adjustments			
	Changes	Increases	Decreases	Fraction of price decreases
Consumer goods				
Non-durables, food	35.4	20.1	14.6	41.2
Non-durables, non-food	9.0	5.7	3.3	36.4
Durables	16.6	11.2	5.4	32.4
Capital goods	13.0	8.9	4.1	31.2
Intermediate goods	29.3	17.6	11.6	39.7

Note: Estimates are given in percent, average share of prices changed per month. How the different sectors have been grouped in the product categories can be seen in Table A3 in the appendix.

Gautier (2008) highlights a great advantage with micro data of the type used in this paper, namely that it allows for analysis and comparison across sectors, and also product groups. A further analysis of the Norwegian dataset shows that there is considerable variation in the price change frequency across different product groups, which is consistent with what is documented in the similar research from Europe. So there is variation in the degree of price rigidity across producers of different goods, and this implies that different producers have different ways of dealing with shocks in the economy. This further means that the impact of macroeconomic policies by the central bank is not homogeneous across the whole economy, a finding that should be included in the central bank's model formulation. However, this is something that most theoretical models today do not take into account (Álvarez et al. 2010).

Table 3 shows the total change frequency, and also the frequency of increases and decreases separately, by intermediate goods, capital goods and consumer goods. Consumer goods are further decomposed into foods, non-durable consumer goods other than food, and consumer durables.

Worth emphasizing is that the frequency of price adjustments is never at a value close to one, regardless of product category. This means that the price change is not as frequent as several of the established DSGE models suggest, as presented in chapter 2. These findings thus indicate that there indeed are rigidities at the PPI level that several of the traditional macro models are unable to account for.

The estimated frequencies are ranging from 9 percent to over 35 percent, indicating that food manufacturers change their rates significantly more often than manufacturers in other groups.

The comparable literature usually point out food and intermediate goods (along with energy) as the commodity groups with the highest price change frequency. This is consistent with what the Norwegian data shows.

We also see that there is quite a large variation in the share of price decreases in different product categories. Manufacturers of food products and intermediate goods are also here on top, with a decrease ratio of 40 percent. Fabiani et al. (2010) also find that these product groups stand out, and present as a possible explanation that the production of these goods are more directly affected by international commodity prices. This makes them more volatile, both in a positive and negative direction.

Figure 3 shows the price change frequency in different industries, defined by the SIC2002 2-digit codes[12]. This figure underlines the fact that there is marked heterogeneity in price setting across different types of producers. The difference between the sector with lowest average frequency and the highest frequency is more than 60 percentage points. This figure thus supports the findings of Table 3, though focusing on sectors instead of product groups. The adjustment pattern of producers in the Norwegian manufacturing sector is clearly not as homogenic as many of the presented DSGE models assume. There are marked heterogeneity, both between different product groups and different industries, and the degree of price rigidities is therefore also inconsistent across various producers.

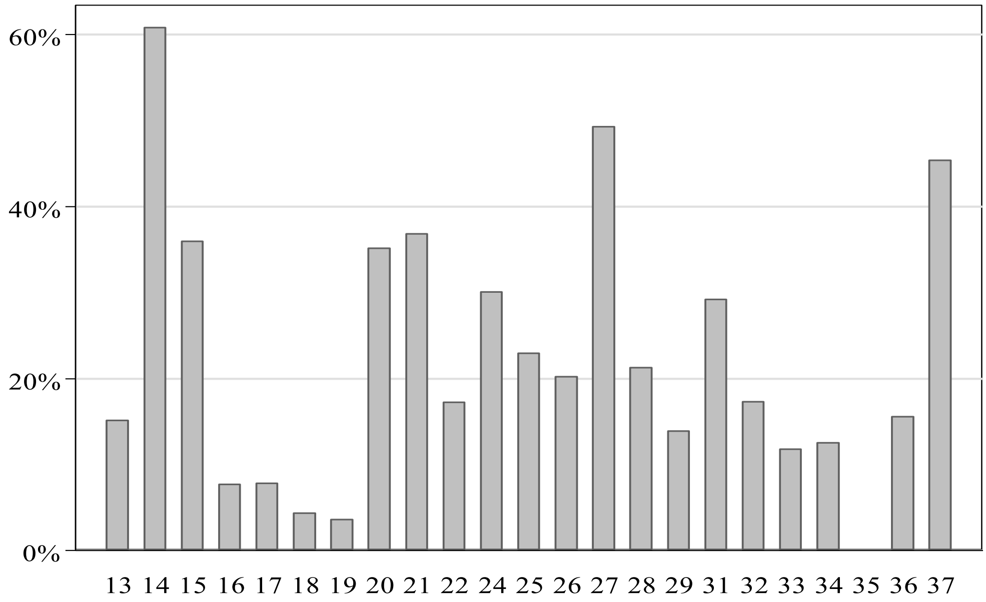
The price data show heterogeneity across industries and product groups, but this is not the only area where heterogeneity is observable in the dataset. A common finding in the empirical analysis is that the price change rate has a seasonal pattern, and varies throughout the year. This is also a central finding of this analysis, as already mentioned when presenting Figure 2. Seasonal peaks can be observed throughout all the years covered by the dataset.

Figure 4 shows a picture similar to what is observed in Figure 2, with aggregated estimates of the average change rate for each month of the year. It is quite easy to spot a pattern. The change rate is at a peak at the beginning of the year. Around 35 percent of the prices change in January, far higher than what is the case for the rest of the year. The change frequency decreases towards the summer months, then increasing slightly again at the start of the second half of the year, before hitting a low point in November and December. This is a recognizable pattern from the literature on both the consumer and producer levels. Also the magnitudes, i.e.

[12] See Table A2 and A3 in the appendix for a complete listing of SIC2002 industry codes.

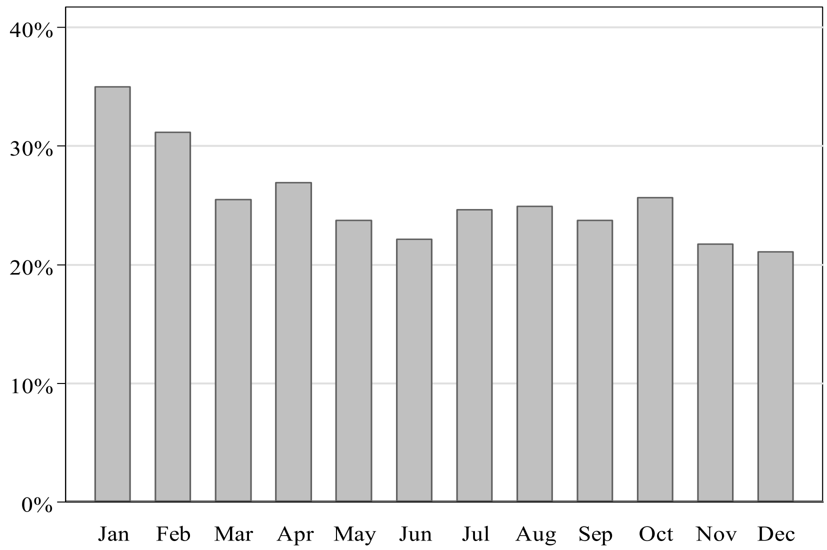
the estimated averages of the frequencies in the different months, are similar to what is observed and documented by Vermeulen et al. (2012).

FIGURE 3 – AVERAGE MONTHLY PRICE CHANGE FREQUENCIES, BY SECTOR



Note: See Table A2 in the appendix for a list of sectors at a 2-digit SIC2002 level.

FIGURE 4 – AVERAGE CHANGE FREQUENCY, BY MONTH



Note: Figures presented are average change frequency per month in the period 2004-2009

Vermeulen et al. (2012) point out three possible explanatory factors behind the observed seasonal pattern. First of all, wages are more frequently adjusted in January. This could be passed on to the prices of the products, as labor cost is considered to be an important determinant of producer price setting. Secondly, the price change pattern could be due to seasonal demand fluctuations, for example related to Christmas or summer seasons. The third mentioned factor that could explain the pattern is seasonality in signing of price contracts. Contracts, either implicit or explicit, are usually renegotiated on certain time intervals, and the beginning of a new year is not an unnatural choice in that respect.

It may also be interesting to compare the price change frequency on producer level with the frequency found on consumer level. The change frequency on consumer level is found to be approximately 20 percent (Wulfsberg 2009)[13]. The mean frequencies of price increases and decreases are 12 percent and 8 percent, respectively. Hence, compared to the findings from the PPI dataset, presented in Table 2 the Norwegian consumer prices seem to have a significantly lower change frequency, around 5 percent lower than the producer level frequency. The finding that consumer prices are more rigid than producer prices - in the sense that the change frequency is lower - is supported by similar price adjustment literature. The same goes for the relative sizes of the differences, i.e. the observation that producer level change frequency is 5-6 percentage points higher than the consumer level frequency[14].

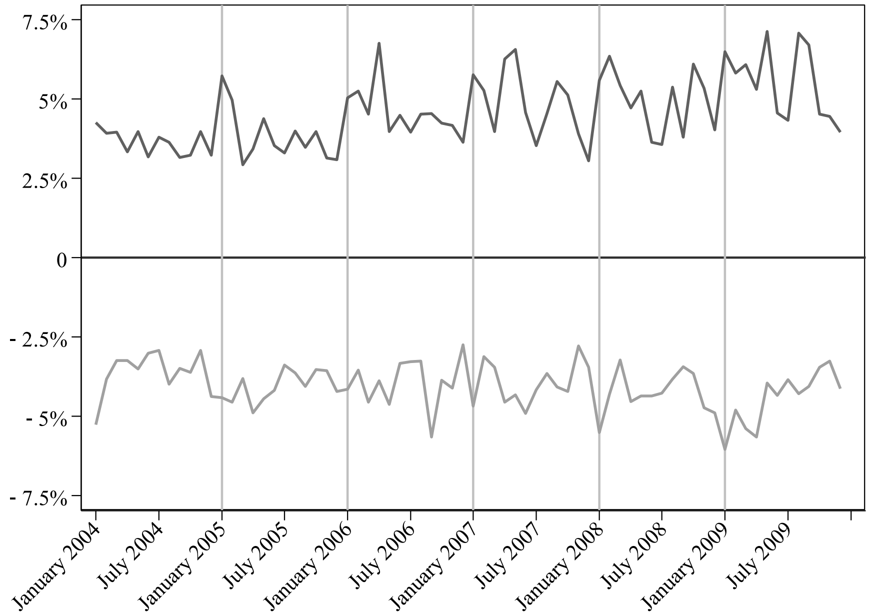
5.2 THE SIZE OF PRICE CHANGES

Next step of the empirical work is to analyze the size of price changes. Once again I start off by studying how the price adjustment is conducted over time. Figure 5 shows the monthly average size of price changes from January 2004 to December 2009. The pattern is a little less clear than it was for the price change frequencies, but also the sizes of price changes seem to follow a seasonal pattern, at least to a certain extent. The beginning of each new year appears to be used as an opportunity to increase prices more than average in size – and not only more frequently than the rest of the year. Such a pattern is less easily spotted for price decreases.

[13] This thesis does not examine the consumer level price adjustments explicitly, but Wulfsberg (2009) summarizes micro evidence from Norwegian consumer price data in the period 1975-2004. The 20 percent estimate is for the 1990-2004 period. For the early period (1975-1989) the mean frequency is a little higher at 23.7 percent, for the full dataset the mean frequency is 22 percent.

[14] Vermeulen et al. (2012) refer to a change frequency of 21 percent for producer prices and 15 percent for consumer prices.

FIGURE 5 – MONTHLY SIZE OF PRICE CHANGES



That also the sizes of price adjustments follow a seasonal pattern is supported by the earlier literature on the field.[15]

The average value of a price increase on the production level in Norway is 4.8 percent. For price decreases the figure is slightly lower at 4.1 percent, but it is still reasonable to argue that there is a fairly balanced relationship between adjustments up and down in terms of size. This can also be seen from Figure 5. The absolute size of price increases and decreases seem to mirror each other fairly well throughout the studied time period. The Norwegian average figures are also of the same magnitude as for Europe as a whole, for which an average size of price change of 4 percent in both directions is reported (Vermeulen et al. 2007).

We observe from Table 4 that the size of price changes varies across the different product groups. Looking back at the distribution of frequencies, given in Table 3, it appears to be some sort of trade-off between frequency and size of the changes. The product groups apparently compensates for lower frequency of change through larger sized price changes, and vice versa. As an example, non-durable consumer goods (non food) do have the lowest change frequency, but at the same time the largest changes in absolute value, while the food

[15] Cornille and Dossche (2008), for example, regress the absolute value of price changes on a constant and 11 monthly dummies, and find a significant January effect. Such a regression has not been reproduced in this thesis.

and drinks are at the opposite end of the scale with highest frequency and smallest average changes.

Table 5 shows comparative statistics for the size of price changes. Price changes at the Norwegian producer level have several similarities with the price changes in European countries when looking at the size. The median of price increases and decreases are respectively 2.8 percent and 2 percent. For the price increases, this is identical to what is observed in Europe. For price decreases the figure is marginally lower than the European average, but still in line with a number of comparable countries.

TABLE 4 – SIZE OF PRICE ADJUSTMENTS, BY PRODUCT CATEGORIES

	Size of price adjustments	
	Increases	Decreases
All items	4.8	4.1
Consumer goods		
Non-durables, food	3.7	3.5
Non-durables, non-food	5.9	5.1
Durables	5.8	5.3
Capital goods	5.5	4.4
Intermediate goods	5.0	4.2

Note: The estimates are average absolute value of the price changes, given as percentages.

TABLE 5 – SIZE OF PRICE CHANGES

	Size of price increases			Size of price decreases			
	1st quartile	Median	3rd quartile	1st quartile	Median	3rd quartile	Inflation
Belgium	1.2	3.0	6.2	1.6	3.7	7.5	0.12
France	0.9	2.8	4.7	0.6	1.9	4.8	0.09
Germany	0.9	2.1	4.1	0.7	2.0	4.8	0.09
Italy	1.9	3.2	5.1	1.9	3.1	4.9	0.14
Portugal	3.4	6.9	11.8	3.4	6.9	11.8	0.17
Spain	1.4	3.1	6.1	0.8	2.5	5.8	0.17
Euro area	1.3	2.8	5.0	1.1	2.5	5.2	0.11
Norway	0.9	2.7	5.6	0.6	2.0	5.0	0.17

Note: The estimates are absolute values of price increases and decreases, given as percentages. For the other European countries the estimates are taken from Vermeulen et al. (2012). The Norwegian inflation figure is average monthly change in CPI from 2004 to 2009.

The quartiles in Table 5 indicate that 50 percent of the price increases and decreases are in the interval between approximately 1 and 5 percent. Furthermore, the analysis shows that more than one tenth of both increases and decreases are higher than 10 percent[16]. Large price changes are thus *not* unusual. Vermeulen et al. (2007) get similar results, and argue that the adjustment costs therefore probably not follow a convex pattern (which is the prerequisite of some of the DSGE models presented in chapter two). Convexity would imply that large price changes are more expensive and therefore uncommon.

Table 5 also shows that the price changes are substantial compared to the prevailing rate of inflation in each country. The average price change of around 4 percent is many times greater than the monthly inflation rate. Cornille and Dossche (2008) get similar results, and interpret this as evidence that large, idiosyncratic shocks underlie producers' price change pattern. This argument is supported by the coexistence of upward and downward price adjustment (Cornille and Dossche 2008).

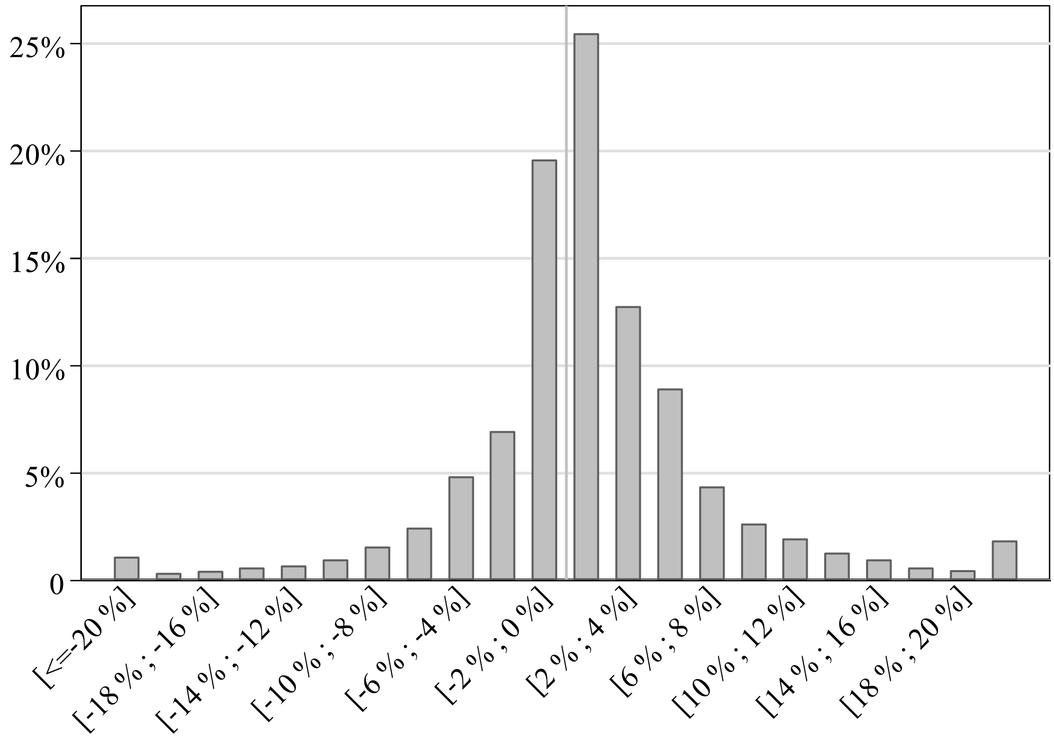
When the findings for price change frequency were presented earlier in the analysis, the estimates showed that there is a certain indication of downward nominal rigidity. The basis for this was a relatively lower share of price decreases, and as already noted such rigidity may occur if the distribution of price changes is skewed. Graphically this may be presented as in Figure 6, where the distribution of the price change sizes is shown in 2 percentage point intervals.

Figure 6 gives support to the findings related to the share of price decreases. We see that there is some degree of misalignment towards the right side of the distribution. This is particularly evident on the small price changes, centered around zero. A simple eyeball test thus relates the lower frequency of price reductions to the fact that there is a lower number of small price changes on the negative side than it is on the positive side. Such a finding is shared by Cornille and Dossche (2008) among others, but the skewness is somewhat larger for the Norwegian data.

As with the price change frequency findings, we can also compare the size of price changes on producer level to what has earlier been found on the consumer level. Wulfsberg (2009) reports mean sizes of price increases and decreases to be approximately 12 percent and 10.5 percent, respectively. Comparing these estimates to the figures presented in Table 4 proves

[16] These percentiles are not reported in the table.

FIGURE 6 – DISTRIBUTION OF PRICE CHANGE SIZES



Note: Figures given as percentage shares of different intervals in the distribution.

that consumer level price setting again differs from producer level price setting. The differences are striking. The CPI adjustments are more than double of the PPI adjustments in absolute size. These findings may appear extreme, but are also supported by the general price setting literature[17].

5.3 THE DURATION OF PRICE SPELLS

As already mentioned there are several considerations that must be made before estimating the duration of price spells. Álvarez al. (2010) emphasize that the implicit estimation of duration through the frequency approach has distinct advantages when it comes to the amount of data that is included in the analysis. Nevertheless, in order to observe the full distribution of price changes it is also necessary to utilize the direct duration approach estimation, with an assessment of correction for censored data.

[17] Vermeulen et al. (2012) present prices adjustments of 9 percent and 4 percent for consumer prices and producer prices.

The reference literatures have different ways of dealing with the subject. Veronese et al. (2005) present two different strategies, respectively no correction for censored data, and full correction for censored data. The former strategy thus ignores the issue completely, and consequently utilizes all price spells in the dataset, regardless of whether they are censored or not. The second strategy eliminates the first and last price spell of each price trajectory, and duration estimates are therefore based only on the remaining price spells, for which the true start and end period is known. This means that many price spells disappears from the dataset, and the products with a least frequent price change pattern are at the greatest risk of being removed from the dataset.

To see what choice of method has to say for the analysis of the Norwegian data, I will start by calculating the average duration of the various methods presented above.

The implicit estimation method through the frequency approach, i.e. by using the inverse of the change frequency according to equation (6) in the methodology chapter, provides a mean duration of 3.9 months. With the direct duration approach, without correcting for censored price spells, the average duration is 3.7 months. This is exactly the same we would get by using the frequency approach if we had not corrected for the first month of each price trajectory[18]. As mentioned in the methodology section, this is expected as the frequency and duration approach yields equal results in datasets without censored price trajectories.

The estimate of average duration when using the duration approach with full correction for censored price paths is 2.9 months. This clearly shows that how you choose to deal with censored data does have a lot to say. With full correction for censored data, i.e. elimination of both right and left censored spells, as much as 26,500 price quotations are eliminated from the dataset. This represents one third of the dataset, and the consequence is that a large amount of long price spells disappear from the estimation. The proportion of short price spells rises, and the average duration will therefore be lower.

Table 6 shows the distribution of price durations. In order to get a proper case for comparison the construction of this table imitates the one of Table 4 in Álvarez et al. (2010), where similar results are presented for Spanish producer prices. Álvarez et al. approach the question of dealing with censored data by including only non-left censored price spells in the estimation. In other words, right censored price spells are not removed from the dataset.

[18] Both methods would then produce an average duration of 3.699 months.

TABLE 6 – DURATION OF PRICE SPELLS

	Observations	Mean	Min	1st quartile	Median	3rd quartile	Max
All items	20417	3.4	1.0	1.0	1.0	3.0	72.0
Consumer goods							
Non-durable, food	5392	2.6	1.0	1.0	1.0	2.0	72.0
Non-durable, non-food	592	8.0	1.0	1.0	2.0	12.0	72.0
Durables	1079	5.3	1.0	1.0	2.0	9.0	52.0
Capital goods	1551	6.1	1.0	1.0	4.0	10.0	72.0
Intermediate goods	11803	3.0	1.0	1.0	1.0	2.0	72.0
After a price increase							
All items	12497	4.1	1.0	1.0	1.0	5.0	72.0
Consumer goods							
Non-durable, food	3194	3.0	1.0	1.0	1.0	3.0	60.0
Non-durable, non-food	380	9.8	1.0	1.0	8.0	12.0	72.0
Durables	727	6.5	1.0	1.0	5.0	11.0	52.0
Capital goods	1068	7.1	1.0	1.0	5.0	12.0	48.0
Intermediate goods	7128	3.6	1.0	1.0	1.0	3.0	72.0
After a price decrease							
All items	7920	2.2	1.0	1.0	1.0	1.0	72.0
Consumer goods							
Non-durable, food	2198	1.9	1.0	1.0	1.0	1.0	72.0
Non-durable, non-food	212	4.9	1.0	1.0	1.0	3.0	50.0
Durables	352	2.9	1.0	1.0	1.0	2.0	31.0
Capital goods	483	4.0	1.0	1.0	1.0	4.0	72.0
Intermediate goods	4675	2.0	1.0	1.0	1.0	1.0	61.0

Note: The estimates are unweighted averages (number of months) obtained with the duration approach, using non-left censored price spells only. “Observations” refer to number of price spells.

Compared to the different alternatives presented in the above paragraph, this could be interpreted as a middle way between two extremes. Considering that neither of the two extreme solutions produce a perfectly correct picture of the distribution of price spells (full correction of censored data implies eliminating many long price spells, whereas no correction implies keeping price spells for which the true duration is unknown), this “middle way” is the strategy I will follow also in the remaining estimations of this chapter.

Table 6 reveals several interesting findings. One of the most striking features of the table is the amount of prices lasting only a short while. For several of the product categories the median price duration is one month. This is the case even for product categories where the distribution of price durations ranges from one month to 72 months, and is clearly a sign that Norwegian producer level commodity prices tend to last rather short.

Looking at the mean duration estimates we find that prices in average last 3.4 months. This is close to what was estimated a couple of paragraphs above, but a little lower as these estimates have been subject to correction for censored price spells. Once again the data confirm that correcting for censored spells favors the shorter price spells, and produces downward biased estimates.

Even though the estimates may be a little lower than is actually the case, there are several other findings we can highlight in Table 6. First of all, the duration of price spells are considerably longer after price increases than after price decreases. The mean duration of four months after a price increase is the double of what we observe after a price decrease. This is the case for the full sample, but also for each product category separately. That prices last shorter after price decreases is a finding shared by Álvarez et al. (2010), and shows that producers are less willing to keep their price low after a price decrease than they are to reduce their price after a price increase.

Comparing the findings from Table 6 to the findings of Álvarez et al. (2010) reveals that the Spanish estimated durations are higher than the Norwegian estimates. For example they find a mean duration of 5 months for the whole sample, significantly higher than the Norwegian 3.4 percent. Since their figures are also unweighted estimates, one could not claim that this difference is due to the lack of industry weights in my estimation. The reason is thus likely to be linked to differences in the datasets. After all, the estimated change frequency at 21 percent for Spain is lower than the Norwegian 25 percent estimate, and lower change frequency would imply longer price durations by definition. Another possibility is the sample selection of the dataset. The dataset used in this empirical analysis consists of 50 percent intermediate goods and 20 percent food products[19], and these product categories have proven to be the ones with the highest change frequency. However, the same relative selection can be found in the dataset of Álvarez et al. (2010), so this is likely to not be too influential in causing the differences between their estimates and mine.

Figure 7 shows the distribution of price durations, and makes it very clear that there indeed is a large amount of price spells lasting only one month. In the construction of this figure it has been corrected for censored data series in the same way as above, by keeping only non-left censored data. As this figure presents the shares of the specific price durations, one could

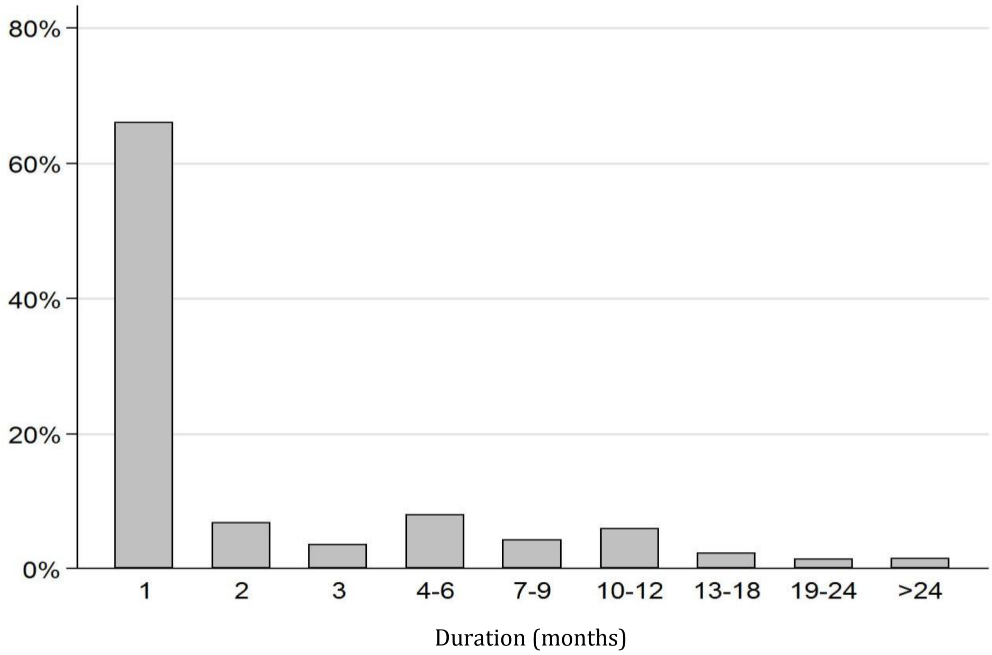
[19] See Table A3 in the appendix

perhaps argue that including censored price spells (which we don't know the true duration of) causes the estimated distribution to be less accurate. However, as has been emphasized several times, the correction for censored data is more likely to eliminate relatively long price spells, and the choice of correction for censored price spells will again serve as a middle way between two more extreme strategies.

A similar figure with full correction for censored data was also made (though not presented in this paper). Naturally, under full correction for censored data, the share of prices lasting only one month is even higher. This further underlines the argument that correction for censored price spells produce artificially high shares of short price spells, causing the average duration to appear lower than is actually the case.

In order to be able to retain some of the longest price spells, and hence reduce some of the downward bias caused by eliminating censored spells, Figure 7 includes censored price spells with a price visible in at least 25 successive under a common label, ">24". This is because it can be said with certainty that these prices have an age that is higher than 24 weeks, although the exact price duration cannot be determined. With such a method only 7656 price quotations are eliminated from the dataset.

FIGURE 7 – DISTRIBUTION OF PRICE SPELL DURATIONS



Note: The figure shows shares of price durations for various intervals. The dataset used to produce this figure has been cleared of left-censored price spells. However, price spells where more than 24 price quotes are observed in the dataset have been included in the estimation under the common label for durations of more than 24 months.

A similar figure can be found in Sabbatini et al. (2005). Their figure of the distribution of price durations in Italy is indeed similar to what we can see from Figure 7, but one difference is striking; the share of prices lasting only one month is slightly over 50 percent, more than 10 percentage points less than the 66 percent estimate given by the Norwegian data. Still, looking back at the frequency statistics from Table 2, we are reminded that the estimated Italian price adjustment frequency is barely over 15% per month, 10 percentage points lower than the Norwegian estimate. Again, a lower change frequency would imply longer average price durations, and the observed differences are thus not so surprising after all.

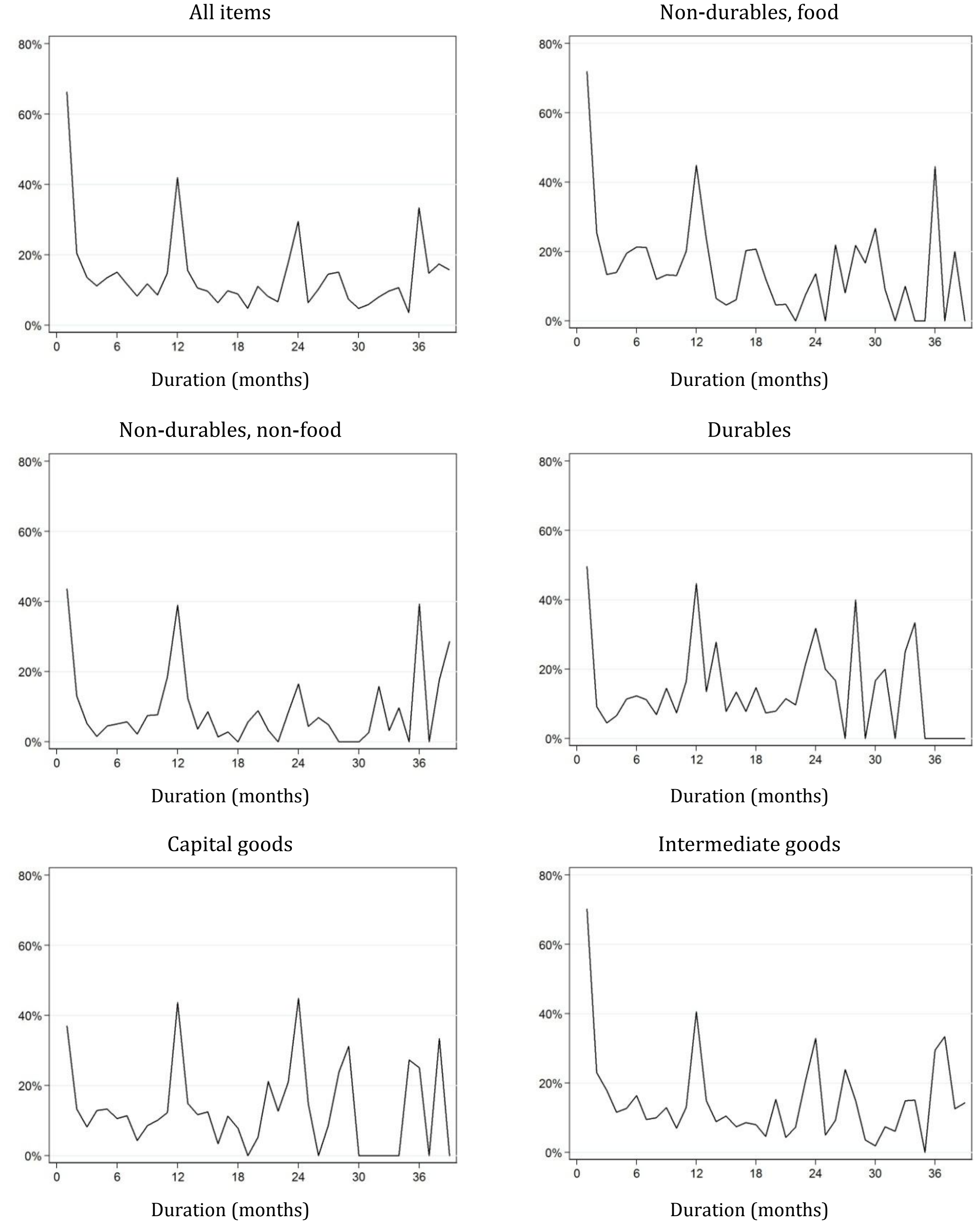
In the further analysis of the price spells' duration hazard functions have been estimated for the dataset as a whole, as well as for the five different product groups individually. As described in the methodological section, these hazard functions allow us to learn more about the price change pattern for various price durations. Similar to the previous estimates of this sub-chapter, correction for left-censored data have been conducted before obtaining these estimates. The result is shown in Figure 8. The figures show clear parallels to what is documented in the literature for other countries.

First of all, it is quite clear that the aggregated hazard rate is a decreasing function of the price durations. This is an important finding, as most macro models assume constant hazard rates. The higher the age of a price spell, the lower is the probability that the price will die. This may seem counter-intuitive, but is a key finding previous PPI analysis (see for example Álvarez et al. 2010 and Veronese et al. 2005).

The declining trend of the hazard functions can be explained by looking at differences in adjustment probability between different manufacturers. The probability of price changes is by definition lower for products with high price duration than for products with low price duration. The hazard rates are, however, *aggregate* estimates across different products. In the construction of such an aggregated graph it will therefore be the case that the share of prices set by manufacturers with a more frequent change pattern goes down the longer the time horizon is. Put differently, several heterogeneous producers with non-decreasing hazard functions yields a decreasing hazard function when aggregated. For long durations mostly manufacturers with relatively low change frequency remain (Álvarez et al. 2005).

For some disaggregated figures, at assumed more homogenous levels, it does indeed seem like the hazard rates are more constant. However, in Figure 8, we can also observe that several product groups show clear signs of declining hazard functions. This implies that there is heterogeneity also within these groups resulting in falling curves of the hazard rates, e.g. on a sectoral level (Álvarez al. 2010). This assumption is supported by the observed heterogeneity between different SIC2002 sectors (see e.g. Figure 3).

FIGURE 8 – HAZARD RATES



Note: The hazard rates are given as percentages. The horizontal axis has been cut at 40, due to a low number of observations for prices older than this. The dataset used has been cleared of left-censored price spells.

Another observation is that a considerable share of the prices dies out after a very short while, often after only one month. This is something we have already observed in the distribution of price durations (Table 6 and Figure 7), and in Figure 8 this can be e seen as very high rates for the first month. The probability of price change after only one month is consistently high across the dataset, with share up towards 70-80 percent for the product groups with the highest change frequency. After this early peak the hazard rates plunge down to a considerably lower level. However, as mentioned in relation with Figure 7 the proportion of first month changes is probably somewhat exaggerated, since at the correction for censored data is more likely to eliminate relatively long price spells.

A third observation is the existence of clear peaks every twelve months, as we have observed also in other parts of the analysis. This is also a well-known finding from the earlier PPI literature, indicating that a large proportion of price setters set prices only once a year. Furthermore, this could be interpreted as an acceptance of price setting in a Taylor or Calvo pattern among some producer price setters in Norway, in the sense that a fraction of the producers re-price their products on fixed intervals. However, as will be made clear when the findings of this thesis is summarized, this alone is not necessarily enough to accept neither of these models in their original form.

The findings presented in the paragraphs above are consistent across the dataset and provides good grounds for evaluating the conformity of established pricing models. However, perhaps with the exception of the estimate for the dataset as a whole, all of the hazard rates indicate that a larger set of observations would be beneficial for the estimation. This is particularly evident for high price ages, as the graphs have numerous short lasting peaks of great magnitude, indicating a low number of price spells to base the hazard rate estimation on.[20] A rather limited number of observed price spells with durations in the high end of the distribution results in hazard rates jumping a lot up and down without any clear pattern. Still, the decreasing pattern of the hazard rates is quite clear for the shorter price durations, and especially for the estimates based on the bigger parts of the data sample.

[20] The graphs have been cut at duration = 40, because of the low number of durations higher than this. Appendix 4 contains a list with number of price spells at various durations and different product groups.

6. CONCLUSIONS

We have only limited knowledge about how Norwegian producers change their prices. The aim of this thesis has therefore been to gain greater insight in the price adjustment on producer level in Norway. Throughout the paper I have gathered evidence on the adjustment patterns of Norwegian producers within manufacturing, mining and quarrying. Light has been shed on the field through the presentation of a wide range of descriptive statistics.

6.1 SUMMARY OF FINDINGS

The price change frequency of Norwegian producers is slightly above 25 percent every month. The findings thus indicate that the price adjustment is done in a relatively unfrequent manner, and not in continuous time as several of the presented macro models assume. The analysis also reveals that price increases are more common than price decreases. Furthermore, producer prices appear to be less rigid than consumer prices, as the price change frequency is approximately 5 percentage points higher for the former..

The price change frequency shows great heterogeneity between different product categories. This means there are differences in the degree of rigidity, and thus in the reaction pattern of different producers in the wake of macroeconomic shocks. This is an empirical fact many of the pricing models don’t take into account. The frequencies range from 9 percent to 35 percent, indicating that producers of food products and intermediate goods adjust their prices much more frequently than producers of other product groups. Heterogeneity is also evident when we observe the change frequencies of various sectors at a two-digit SIC2002 level.

Another kind of heterogeneity is found when observing price change frequency in different months. There are clear signs of seasonality in the price adjustment pattern of firms, as the frequency has substantial peaks in January every year. This is evidence disproving several of the macro models assessed in this thesis, as they assume constant hazard rates over time.

When it comes to the size of price changes, we observe that the average size of price increases is just below 5 percent, while the average price decreases are slightly over 4 percent, although there is heterogeneity between different product categories, here as well. The price changes are sizeable compared to the average inflation observed for the sample period. Large absolute value price change is considered to be one of the factors indicating rigid prices (Gautier

2006), and the distribution of price change sizes reveals that large price changes are not unusual. This indicates that the adjustment costs do not follow a convex pattern, which some of the macro models assume. At the same time, however, the data show that a large proportion of the price spells last only one month. This is inconsistent with several of the presented macro models, which assume fixed interval adjustment of prices. However, this finding does not necessarily imply that the models assuming continuous adjustment are more correct, as the data clearly show that the adjustment to a large extent is executed on an infrequent basis.

When analyzing the price spell durations, we find that the mean duration of price spells for the full sample is between 3 and 4 months. Another finding from the price duration distribution is that price spells last significantly longer after price increases than price decreases. The mean duration after price increases is almost double the duration after price decreases, regardless of which product category we observe.

Constructing hazard rates also gives interesting results. The hazard rates of Norwegian producers are declining, both at the aggregated level and across different product categories. This is an important observation as most macro models of today assume constant hazard rates.

Comparing the findings of this thesis to the European reference literature (summarized by Vermeulen et al. (2012)) shows that Norwegian producers' pricing pattern is more or less in line with what is observed for the rest of Europe. In some of the estimations the Norwegian figures admittedly seem to differ somewhat from the European averages, for example in change frequencies. However, the Norwegian figures are never far away from the ones of other countries, if not necessarily hitting the exact average. Additionally, the reference literature show that the figures from the other European countries also differ a lot in between each other. It is not unnatural to assume that Norway would do the same.

One could ask what choice of aggregation, i.e. leaving out industry weighing, has had to say on the results. Yet, with the results from the empirical analysis at hand, I would again claim that this has been of little consequence. For parts of the analysis, e.g. when presenting the distribution of price durations, unweighted estimations from reference countries have been available for comparison with my unweighted figures. These findings are backing up findings from other parts of the analysis, for which unweighted reference figures have not been available. Put differently, the above-average change frequency estimates, for example, is supported by the relatively low price spell durations. I would claim that such consistency provides increased credibility to the findings of this thesis.

6.2 IMPLICATIONS

Summing up the findings from this thesis shows that there indeed are signs of rigidities on the producer level in Norway. The producers' prices seem to last longer, have a lower change frequency and larger changes in absolute value than most models of today are able to account for. Additionally, there are clear heterogeneities between different sectors and product categories, and these differences in rigidities must also be taken into account in the macro model design process.

In the empirical analysis of this paper I have presented findings in several areas. Some of these findings can directly be used for assessing the conformity of various DSGE pricing models with micro evidence. Looking back at the models presented in chapter 2, I choose to assess their validity based on a selection of their underlying assumptions, summarized in Table 1. More specifically I assess whether the presented models allow for infrequent adjustment, heterogeneity between producers, and decreasing, non-zero hazard rates with annual spikes, as proven by the micro evidence. These are all central evidence from this thesis and also earlier literature. That I choose to focus on these assumptions does not imply that these are the only ones essential in the respective models' frameworks, simply that these are the factors applicable to my empirical findings.

The selected DSGE models differ substantially in the degree of conformity with the micro evidence, but in general one could say that the majority of the models are unable to account for most of the empirical facts. Among the models failing to incorporate the empirical evidence are the renowned Taylor (1980) and Calvo (1983) models, and researchers have reached increasing consensus about these inaccuracies recent years (see e.g. Carlsson and Skans (2009) and Álvarez and Burriel (2010)). Most of the models are seemingly able to match parts of the evidence in their framework, but few of them, if any, manage to implement the whole range of crucial assumptions.

A key point of the empirical evidence is that producers are *different* economic actors, and thus have different reaction pattern in response to economic shocks. Hence, the simplified assumptions of the DSGE models, with homogenous, continuous adjustments, are not reflecting the actual workings of the economy. To ignore such heterogeneity is dangerous, as research show that real effect of macro shocks in the economy is significantly larger and more persistent in multi-sector economies, than in economies consisting of similar firms with similar adjustment patterns (Álvarez 2008).

Consequently, as indicated in the introduction of this paper, there is still a need to revise even the most famous and widely adopted macro pricing models. Without trying to undermine the relevance of state-dependent models and other theoretical directions (empirical research does indeed show that state factors are also important), the time-dependent models seem to be best able to account for the empirical evidence presented in this thesis. That time-dependent features and models building on the Calvo framework are relatively more fitting is also supported by findings from earlier pricing literature (e.g. Aucremanne and Dhyne (2005)). Among the models presented in chapter 2, the model of Álvarez et al. (2005) appears to be the closest to picking up the empirical evidence found in this thesis. This model is indeed a modification of the original Calvo model, acknowledging the fact that economic actors are heterogeneous, and thereby being able to account for the downward sloping hazard rates, as proven in the empirical literature.

However, having constructed a DSGE model able to account for the empirical facts presented in this thesis does not necessarily make it a perfect fit, as there undoubtedly are crucial factors not emphasized in this work. Nor has identifying the perfect design of the DSGE models been the aim of this thesis, rather to make an assessment of the already existing models. The inflation dynamics and the workings of the heterogeneous economy is indeed a multifaceted field of research, which ultimately explains the wide range of differing views on price adjustment and price rigidities. Discovery and implementation of new empirical facts into macro models is therefore still needed in order to further optimize the macro policies and their implications for the economy.

APPENDIX

APPENDIX 1: COMPARABLE PPI LITERATURE

TABLE A1

Country	Reference	Sample period
Belgium	Cornille and Dossche (2008)	January 2001 – January 2005
France	Gautier(2008)	January 1994 – June 2005
Germany	Stahl (2006)	January 1997 – February 2003
Italy	Sabbatini et al. (2005)	January 1997 – December 2002
Portugal	Dias, Dias, and Neves (2004)	January 1995 – December 2002
Spain	Àlvarez, Burriel and Hernando (2010)	November 1991 – February 1999
Norway	Bratlie (2013)	January 2002 – December 2009

Note: The information in this table is taken from Vermeulen et al. (2012)

APPENDIX 2: INDUSTRIES REPRESENTED IN THE DATASET, 2-DIGIT SIC2002

TABLE A2

2-digit code	Industrial activity	Number of price quotes	Share of dataset
13	Mining of metal ores	228	0.24
14	Other mining and quarrying	1644	1.75
15	Manufacture of food products and beverages	18852	20.0
16	Manufacture of tobacco products	264	0.28
17	Manufacture of textiles	3540	3.76
18	Manufacture of wearing apparel; dressing and dyeing of fur	2064	2.19
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	360	0.38
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	9744	10.3
21	Manufacture of pulp, paper and paper products	3540	3.76
22	Publishing, printing and reproduction of recorded media	60	0.06
24	Publishing, printing and reproduction of recorded media	6312	6.70
25	Manufacture of rubber and plastic products	5868	6.23
26	Manufacture of other non-metallic mineral products	9228	9.79
27	Manufacture of basic metals	1104	1.17
28	Manufacture of fabricated metal products, except machinery and equipment	8664	9.20
29	Manufacture of machinery and equipment n.e.c.	9240	9.81
31	Manufacture of electrical machinery and apparatus n.e.c.	1608	1.71
32	Manufacture of radio, television and communication equipment and apparatus	1464	1.55
33	Manufacture of medical, precision and optical instruments, watches and clocks	2628	2.79
34	Manufacture of motor vehicles, trailers and semi-trailers	1944	2.06
35	Manufacture of other transport equipment	48	0.05
36	Manufacture of furniture; manufacturing n.e.c.	5556	5.90
37	Recycling	252	0.27

Note: Shares are given as percentages. Industry codes and classifications have been collected from SSB (2013c) (Norwegian classification SIC2002) and Eurostat (2005) (NACE Rev. 1.1 classification).

Appendix 3: Industries by product categories, 3-digit SIC2002

TABLE A3

3-digit code	Industrial activity	Number of price quotes	Share of dataset
Non-durables, food		18384	19.5
151	Production, processing and preserving of meat and meat products		
152	Processing and preserving of fish and fish products		
153	Processing and preserving of fruit and vegetables		
154	Manufacture of vegetable and animal oils and fats		
155	Manufacture of dairy products		
158	Manufacture of other food products		
159	Manufacture of beverages		
160	Manufacture of tobacco products		
Non-durables, non-food		7560	8.0
174	Manufacture of made-up textile articles, except apparel		
175	Manufacture of other textiles		
177	Manufacture of knitted and crocheted articles		
182	Manufacture of other wearing apparel and accessories		
191	Tanning and dressing of leather		
193	Manufacture of footwear		
222	Printing and service activities related to printing		
244	Manufacture of pharmaceuticals, medicinal chemicals and botanical products		
245	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations		
364	Manufacture of sports goods		
Durables		7704	8.2
297	Manufacture of domestic appliances n.e.c.		
323	Manufacture of television and radio receivers, sound or video recording		
334	Manufacture of optical instruments and photographic equipment		
361	Manufacture of furniture		
362	Manufacture of jewellery and related articles		
Capital goods		13404	14.2
281	Manufacture of structural metal products		
282	Manufacture of tanks, reservoirs and containers of metal; manufacture of central heating radiators and boilers		
291	Manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines		
292	Manufacture of other general purpose machinery		
293	Manufacture of agricultural and forestry machinery		
294	Manufacture of machine tools		
295	Manufacture of other special purpose machinery		
311	Manufacture of electric motors, generators and transformers		
322	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy		
331	Manufacture of medical and surgical equipment and orthopaedic appliances		
332	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process		

	control		
342	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semitrailers		
343	Manufacture of parts and accessories for motor vehicles and their engines		
351	Building and repairing of ships		
Intermediate goods		47256	50.2
131	Mining of iron ores		
132	Mining of non-ferrous metal ores, except uranium and thorium ores		
142	Quarrying of sand and clay		
143	Mining of chemical and fertilizer minerals		
145	Other mining and quarrying n.e.c.		
156	Manufacture of grain mill products, starches and starch products		
157	Manufacture of prepared animal feeds		
171	Preparation and spinning of textile fibers		
172	Textile weaving		
173	Finishing of textiles		
176	Manufacture of knitted and crocheted fabrics		
201	Sawmilling and planning of wood; impregnation of wood		
202	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fiber board and other panels and boards		
203	Manufacture of builders' carpentry and joinery		
204	Manufacture of wooden containers		
211	Manufacture of pulp, paper and paperboard		
212	Manufacture of articles of paper and paperboard		
241	Manufacture of basic chemicals		
243	Manufacture of paints, varnishes and similar coatings, printing ink and mastics		
246	Manufacture of other chemical products		
251	Manufacture of rubber products		
252	Manufacture of plastic products		
261	Manufacture of glass and glass products		
262	Manufacture of non-refractory ceramic goods other than for construction purposes; manufacture of refractory ceramic products		
265	Manufacture of cement, lime and plaster		
266	Manufacture of articles of concrete, plaster and cement		
267	Cutting, shaping and finishing of ornamental and building stone		
268	Manufacture of other non-metallic mineral products		
271	Manufacture of basic iron and steel and of ferro-alloys		
274	Manufacture of basic precious and non-ferrous metals		
275	Casting of metals		
285	Treatment and coating of metals; general mechanical engineering		
286	Manufacture of cutlery, tools and general hardware		
287	Manufacture of other fabricated metal products		
312	Manufacture of electricity distribution and control apparatus		
313	Manufacture of insulated wire and cable		
315	Manufacture of lighting equipment and electric lamps		
321	Manufacture of electronic valves and tubes and other electronic components		
333	Manufacture of industrial process control equipment		
371	Recycling of metal waste and scrap		

Note: This grouping of industries is based on a similar table from Vermeulen et al. (2007), in which 3-digit NACE codes are distributed across commodity groups. The SIC2002 classification is based on NACE Rev. 1.1 and the grouping is therefore applicable also for the Norwegian dataset.

APPENDIX 4: NUMBER OF PRICE SPELLS, BY PRICE SPELL DURATION (HAZARD)

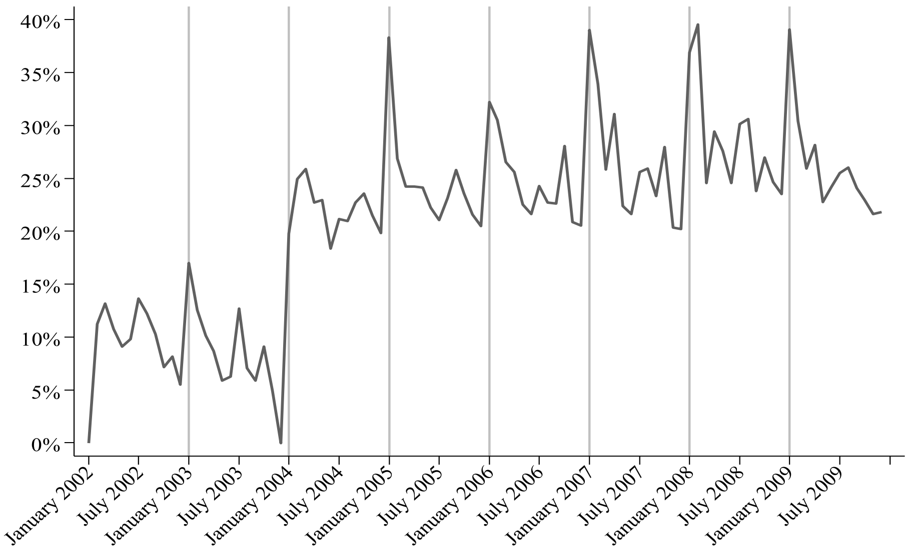
TABLE A4

Price spell duration	All items	Non-durables, food	Non durables, non food	Durables	Capital goods	Intermediate goods
1	13544	3883	258	535	574	8294
2	1409	383	43	50	129	804
3	739	150	15	22	69	483
4	527	136	4	31	100	256
5	564	163	12	50	90	249
6	547	144	13	48	62	280
7	360	113	14	38	60	135
8	225	50	5	21	20	129
9	295	49	17	41	38	150
10	188	42	16	18	41	71
11	298	56	36	37	45	124
12	723	100	62	84	141	336
13	155	29	12	14	27	73
14	89	6	3	25	18	37
15	73	4	7	5	17	40
16	43	5	1	8	4	25
17	62	16	2	4	13	27
18	51	13	0	7	8	23
19	25	6	4	3	0	12
20	55	2	6	3	5	39
21	36	2	2	4	19	9
22	27	0	0	3	9	15
23	67	3	5	6	13	40
24	93	5	9	7	22	50
25	14	0	2	3	4	5
26	21	7	3	2	0	9
27	27	2	2	0	2	21
28	24	5	0	4	5	10
29	10	3	0	0	5	2
30	6	4	0	1	0	1
31	7	1	1	1	0	4
32	9	0	6	0	0	3
33	10	1	1	1	0	7
34	10	0	3	1	0	6
35	3	0	0	0	3	0
36	27	4	11	0	2	10
37	8	0	0	0	0	8
38	8	1	3	0	2	2
39	6	0	4	0	0	2
40	2	0	0	0	0	2
41	3	0	0	0	2	1
42	0	0	0	0	0	0
43	1	0	0	1	0	0
44	4	0	4	0	0	0
45	2	0	0	0	0	2
46	2	0	1	0	0	1
47	3	0	2	0	0	1
48	1	0	0	0	1	0
49	2	2	0	0	0	0
50	1	0	1	0	0	0
51	1	0	0	0	0	1
52	1	0	0	1	0	0

Note: Price spell durations given in months. The figures are number of observed price spells for specific spell durations and product categories, used when constructing the hazard rates. The dataset used has been cleared of left-censored price spells.

APPENDIX 5: FREQUENCY OF PRICE CHANGES, 2002-2009

FIGURE A1 – MONTHLY FREQUENCY OF PRICE CHANGES – 2002-2009



A quick look at this figure suggests a suspicious pattern in the frequency. There is a clear shift in the frequency level between the years 2003 and 2004. In 2002 and 2003 the change frequency is fluctuating around 10 percent. From 2004 and onwards, however, the frequency rises sharply, fluctuating around 25 percent and apparently following a slowly increasing trend.

What causes this strong shift in price change frequency? It does not seem reasonable to conclude that such a pattern is due to a general, radical shift in producers' price adjustment behavior. The shift is observable from one month to the next, from December 2003[21] to January 2004. Cleary such a marked change in behavior could not have been coordinated across all producers.

I choose to analyze the dataset to see whether there are differences between the producers reporting their prices in the two time periods, 2002-2003 and 2004-2009 respectively. The dataset shows that there is no clear distinction in the selection of producers in the two time periods. All, or close to all of the producers have price quotes listed in years within both time periods. Nor are there any apparent differences in sectors or product groups over the years.

[21] Additionally, there are no records of price changes in 2003 at all. Fewer price changes in December are a general pattern across all years, but for the remaining dataset these figures are never close to zero.

Further analyses of the producer characteristics in the two periods reveal that the average revenue, employment number and yearly working hours, are somewhat higher for the two first years. There is also a slightly higher share of price increases in these first years of the dataset. This could imply that the selection of producers is different in the two time periods. There is a possibility that this is the case, as SSB's respondents are changing over time in order to secure representativeness, as noted in an earlier chapter.

However, SSB's dynamic selection of respondents alone could not be causing such a drastic shift. This reasoning leads me to suspect that something is not right with the dataset used in the analysis. Or more precise – it leads me to suspect something is not right with the dataset up until 2004. The reason for this is that the average frequency after the shift is much more similar to other European countries' estimated averages than the average frequency we observe for 2002-2003 (see Table 2). What is actually causing the frequency to be so much lower for the early years of the dataset is unclear. Perhaps did SSB's routines or methods of sampling undergo changes in this period?

Due to the lack of consistency in price change frequency I have left out parts of the dataset in the empirical analysis of this thesis. Since the later years cover the majority of the observations and have the strongest similarities with findings from the European literature, I have chosen to base the analysis only on observations from the years 2004-2009[22]. Dropping out the price quotations from 2002 and 2003 reduced the dataset to 80,208 observations[23].

[22] However, all figures and tables in this thesis have also been produces for the full sample period 2002-2009. These can be found in the appendix.
[23] 5016 price quotes from 2002 and 8988 price quotes from 2003 are removed from the dataset.

APPENDIX 6: TABLES AND FIGURES WITH 2002-2009 DATASET

The tables and figures of this thesis have been produced with a dataset covering the period 2004-2009. Why the first two years of the dataset was left out is described in more detail in Appendix 5. However, the figures and tables were produced also for the full dataset, and can be found on the following pages.

Frequency:

TABLE A5 – AVERAGE MONTHLY PRODUCER PRICE CHANGES IN EUROPEAN COUTRIES – 2002-2009

	Frequency of price adjustments			Fraction of price decreases
	Changes	Increases	Decreases	
Belgium	23.6	12.8	10.9	45.9
France	24.8	13.8	11.0	41.9
Germany	21.2	11.8	9.4	44.4
Italy	15.3	8.5	6.8	45.0
Portugal	23.1	13.6	9.5	41.2
Spain	21.4	12.2	9.2	43.2
Euro area	20.8	11.6	9.2	43.8
Norway	23.0	14.1	8.9	38.6

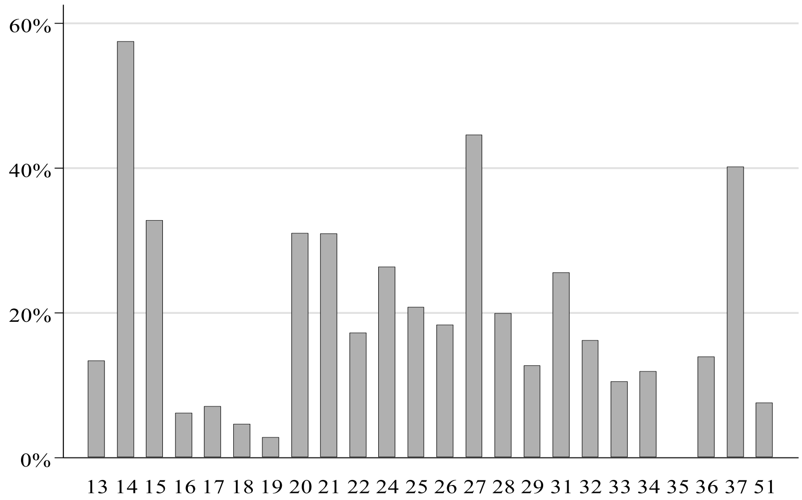
Note: Estimates are given in percent, average share of prices changed per month. For the other European countries the estimates are taken from Vermeulen et al. (2012). A table summarizing the reference literature for the above listed countries is given in Table A1 in the appendix.

TABLE A6 – MONTHLY PRICE CHANGE FREQUENCY, BY PRODUCT CATEGORIES – 2002-2009

	Frequency of price adjustments			Fraction of price decreases
	Changes	Increases	Decreases	
Consumer goods				
Non-durables, food	32.2	19.2	13.0	40.2
Non-durables, non-food	8.4	5.3	3.1	36.4
Durables	14.8	10.1	4.8	32.2
Capital goods	12.0	8.3	3.8	31.2
Intermediate goods	26.2	15.8	10.4	39.6

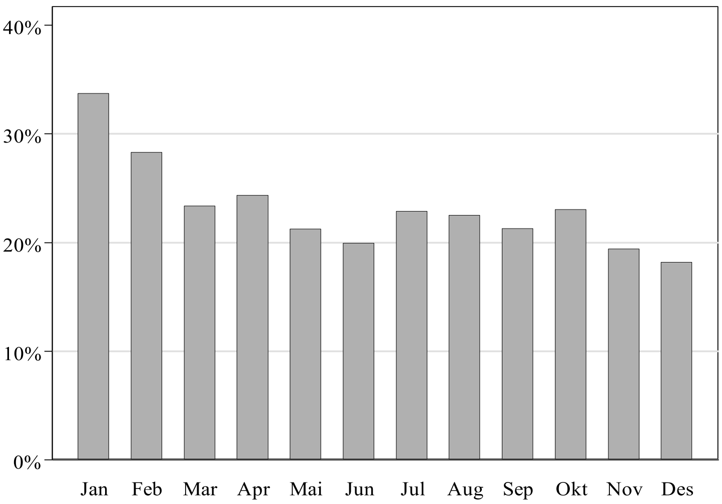
Note: Estimates are given in percent, average share of prices changed per month. How the different sectors have been grouped in the product categories can be seen in Table A3 in the appendix.

FIGURE A2 – AVERAGE MONTHLY PRICE CHANGE FREQUENCIES, BY SECTOR – 2002-2009



Note: See Table A2 in the appendix for a list of sectors at a 2-digit level.

FIGURE A3 – AVERAGE CHANGE FREQUENCY, BY MONTH



Size:

TABLE A7 – SIZE OF PRICE ADJUSTMENTS, BY PRODUCT CATEGORIES – 2002-2009

	Size of price adjustments	
	Increases	Decreases
All items	4.8	4.1
Consumer goods		
Non-durables, food	3.7	3.4
Non-durables, non-food	6.0	5.1
Durables	5.7	5.3
Capital goods	5.5	4.5
Intermediate goods	5.0	4.2

Note: The estimates are average absolute value of the price changes, given as percentages.

TABLE A8 – SIZE OF PRICE CHANGES – 2002-2009

	Size of price increases			Size of price decreases			Inflation
	1st quartile	Median	3rd quartile	1st quartile	Median	3rd quartile	
Belgium	1.2	3.0	6.2	1.6	3.7	7.5	0.12
France	0.9	2.8	4.7	0.6	1.9	4.8	0.09
Germany	0.9	2.1	4.1	0.7	2.0	4.8	0.09
Italy	1.9	3.2	5.1	1.9	3.1	4.9	0.14
Portugal	3.4	6.9	11.8	3.4	6.9	11.8	0.17
Spain	1.4	3.1	6.1	0.8	2.5	5.8	0.17
Euro area	1.3	2.8	5.0	1.1	2.5	5.2	0.11
Norway	0.9	2.8	5.6	0.7	2.0	5.0	0.17

Note: The estimates are absolute values of price increases and decreases, given as percentages. For the other European countries the estimates are taken from Vermeulen et al. (2012). The Norwegian inflation figure is average monthly change in CPI from 2002 to 2009.

FIGURE A4 – MONTHLY SIZE OF PRICE CHANGES – 2002-2009

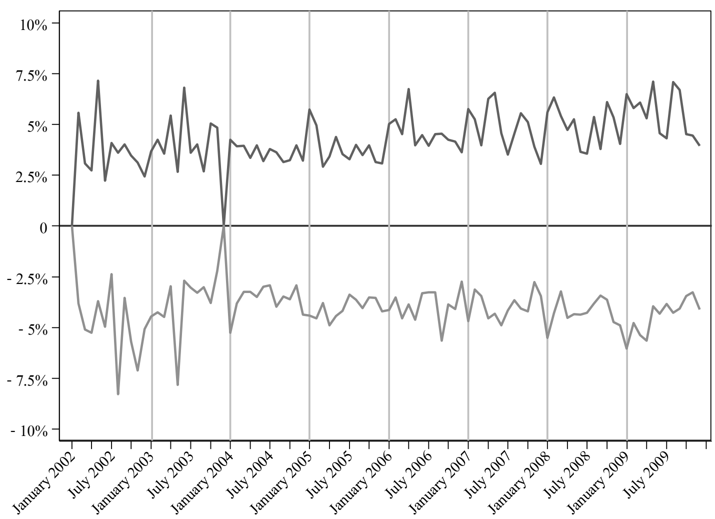
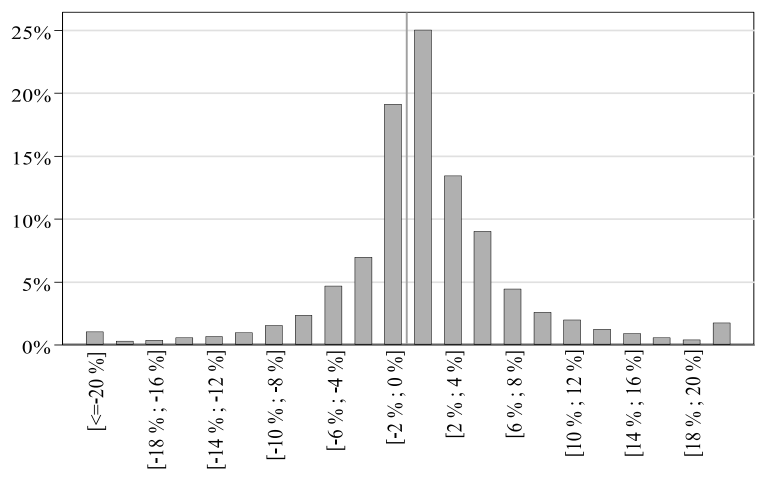


FIGURE A5 – DISTRIBUTION OF PRICE CHANGE SIZES – 2002-2009



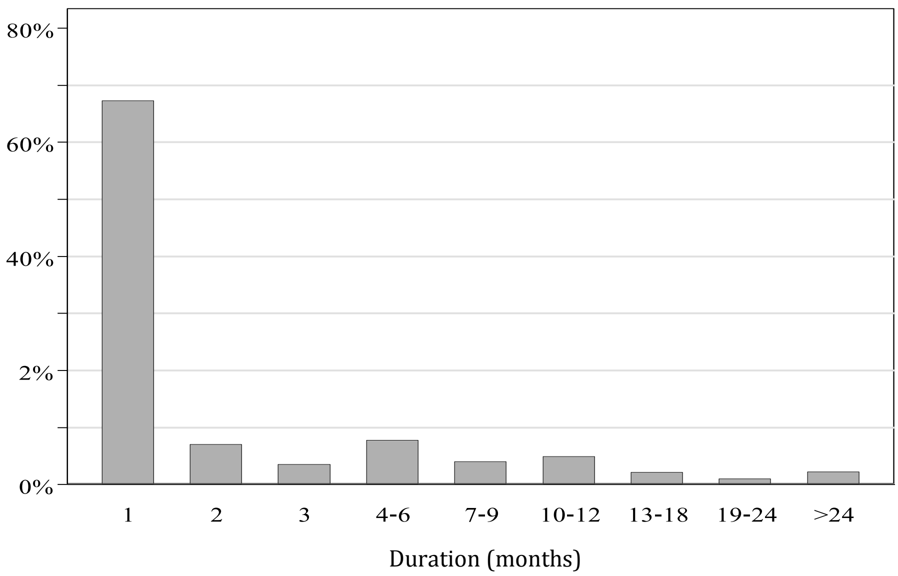
Duration:

TABLE A9 – DURATION OF PRICE SPELLS – 2002-2009

	Observations	Mean	Min	1st quartile	Median	3rd quartile	Max
All items	21258	3.6	1.0	1.0	1.0	3.0	85.0
Consumer goods							
Non-durable, food	5794	2.7	1.0	1.0	1.0	2.0	82.0
Non-durable, non-food	616	8.3	1.0	1.0	2.5	12.0	84.0
Durables	1122	5.7	1.0	1.0	2.0	9.0	56.0
Capital goods	1581	6.3	1.0	1.0	4.0	10.0	85.0
Intermediate goods	12145	3.1	1.0	1.0	1.0	2.0	72.0
After a price increase							
All items	13044	4.3	1.0	1.0	1.0	6.0	84.0
Consumer goods							
Non-durable, food	3464	3.2	1.0	1.0	1.0	4.0	60.0
Non-durable, non-food	390	10.0	1.0	1.0	8.0	12.0	84.0
Durables	761	6.8	1.0	1.0	5.0	12.0	56.0
Capital goods	1088	7.2	1.0	1.0	5.0	12.0	50.0
Intermediate goods	7341	3.8	1.0	1.0	1.0	4.0	72.0
After a price decrease							
All items	8214	2.4	1.0	1.0	1.0	1.0	85.0
Consumer goods							
Non-durable, food	2330	2.0	1.0	1.0	1.0	1.0	82.0
Non-durable, non-food	226	5.3	1.0	1.0	1.0	6.0	50.0
Durables	361	3.4	1.0	1.0	1.0	2.0	37.0
Capital goods	493	4.1	1.0	1.0	1.0	4.0	85.0
Intermediate goods	4804	2.2	1.0	1.0	1.0	1.0	61.0

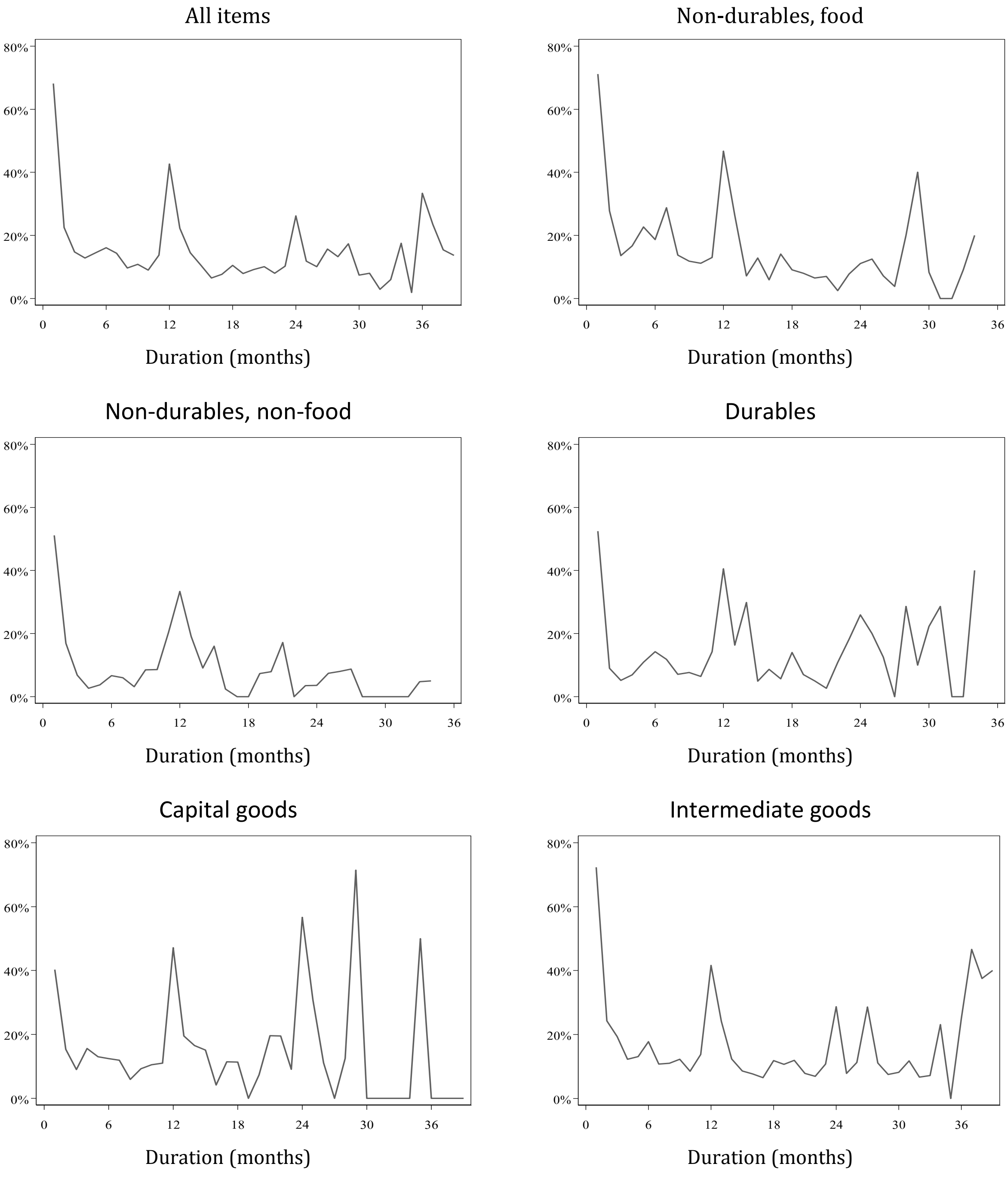
Note: The estimates are unweighted averages (number of months) obtained with the duration approach, using non-left censored price spells only. "Observations" refer to number of price spells.

FIGURE A6 – DISTRIBUTION OF PRICE SPELL DURATIONS – 2002-2009



Note: The figure shows shares of price durations for various intervals. The dataset used to produce this figure has been cleared of censored price spells. However, price spells where more than 24 price quotes are observed in the dataset have been included in the estimation under the common label for durations of more than 24 months.

FIGURE A7 – HAZARD RATES – 2002-2009



Note: The hazard rates are given as percentages. The horizontal axis has been cut at duration = 40, because of a low number of observations for prices older than this.

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